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THE UNIVERSITY OF ALBERTA

Feasibility of Early Screening for Neuromotor Problems in At-Risk Infants: Predictive Validity of the Alberta Infant Motor Scale

by

Johanna Darrah

A thesis submitted to the Faculty of Graduate Studies and
Research in partial fulfillment of the requirements for the
degree of DOCTOR OF PHILOSOPHY IN REHABILITATION SCIENCE

FACULTY OF REHABILITATION MEDICINE

Edmonton, Alberta

Spring 1996

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Abstract

The Alberta Infant Motor Scale (AIMS) is a norm-referenced measure of infant gross motor development and is used to assess the motor development of at-risk infants in neonatal follow-up clinics. This study had two main objectives. The first objective was to identify the percentile ranks on the AIMS that most accurately predict the motor outcome of at-risk infants at 18 months of age and, using these cut-offs, to evaluate the predictive validity of the AIMS compared to the Movement Assessment of Infants (MAI) and the Peabody Developmental Gross Motor Scale (PDGMS). The second objective was to evaluate the theoretical assumption that eventual motor development of children can be accurately predicted from the assessment of their motor skills in infancy.

One hundred and twenty-five infants were recruited from two neonatal intensive care units in Edmonton, and were assessed at 4 and 8 months adjusted ages on three motor measures: the AIMS, the MAI and the PDGMS. A developmental pediatrician assessed each infant at 18 months of age and classified his/her gross motor development as normal, suspicious, or abnormal. Evaluation of a series of cut-off percentiles on the AIMS revealed different percentile ranks for use as cut-offs for the two assessment ages: the 10th percentile at 4 months and the 5th percentile at 8 months. When infants in the suspicious group are included in the abnormal classification sensitivity values obtained on the AIMS and the MAI were similar at 4 months (72.0% vs. 64.0%) and 8 months (80.0% vs. 88.0%). The MAI demonstrated better specificity at 4 months (93.0% vs. 80.0%) while the AIMS had better specificity at 8 months (94.0% vs. 79.0%). Identification of normally developing infants is influenced by the construct of motor development assessed at different ages. The PDGMS performed poorly at both ages and under both classification schemes.

The AIMS demonstrated good predictive validity, thereby supporting the theoretical assumption that early identification of eventual gross motor abilities is feasible.

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Chapter 1

STATEMENT OF THE PROBLEM

1.1.0 Introduction

Low birthweight infants are at increased risk for neurodevelopmental problems, including cerebral palsy (CP) (Kuban and Leviton, 1994; Stanley, 1992), and on-going monitoring of their development at neonatal follow-up clinics is an accepted practice. Full-term infants considered high risk due to documented birth asphyxia are also assessed at neonatal follow-up clinics. Evaluation of gross motor development is often emphasized at the initial assessments since motor abilities are the first observable developmental skills to evolve.

Early screening for motor dysfunction is justified by the theoretical assumptions that: 1) early motor abilities, both normal and abnormal, serve as markers for eventual motor development, and 2) the early identification and treatment of infants with motor dysfunction result in improved outcomes. These two assumptions are interdependent; if early identification of permanent motor dysfunction is inaccurate, a large threat exists to the internal validity of any research attempting to demonstrate the efficacy of early treatment. That is, if early detection of motor dysfunction is inaccurate, many infants who are classified as abnormal in their early motor skills will be identified at a later age as exhibiting normal motor development. If infants with this profile of motor development are included in research to evaluate the efficacy of early treatment, their style of motor development will bias the results since their change in motor classification over time could be attributed falsely to treatment rather than development. This study was designed to evaluate the first

assumption of early screening, that eventual motor function can be predicted accurately by the assessment of early motor abilities.

At present, no standardization exists among neonatal follow-up clinics regarding the most appropriate measure to assess gross motor skills in infancy. The Alberta Infant Motor Scale (AIMS) (Piper and Darrah, 1994) is a new measure to evaluate infant motor skills that is ideally suited for use in neonatal clinics because of its: 1) systematic analysis of components of motor skills, 2) observational format, 3) brevity of administration, and 4) strong psychometric properties. Clinicians working in neonatal follow-up clinics have expressed an interest in using the AIMS to measure the gross motor skills of infants. Because of clinicians' desire to accurately identify infants who may benefit from intervention as early as possible, it is important to evaluate the predictive abilities of the AIMS.

This study had two purposes: 1) to evaluate the predictive validity of the AIMS, and 2) to evaluate the theoretical assumption that early motor abilities predict eventual motor function.

1.2.0 Rationale for the Study

Successful screening for neuromotor dysfunction in at-risk infants requires assessments with good predictive validity. Unfortunately, studies evaluating the predictive abilities of measures currently used to assess infant motor skills report high rates of false positive referrals (Paban and Piper, 1987; Harris, 1987; Harris, 1989; Swanson, Bennett, Shy and Whitfield, 1992). In these studies, many infants who are initially identified as exhibiting suspicious or abnormal motor abilities are categorized as exhibiting normal motor development later in life, thereby resulting in poor specificity rates. This

persisting inability to accurately distinguish between infants with normal and abnormal motor skills may be explained by either one of two reasons: 1) the absence of valid measurement tools, or 2) the false assumption that an infant's early motor abilities are accurate predictors of eventual motor abilities.

The most common explanation forwarded for the poor prognostic record of motor assessments is the inability of available measurement tools to accurately discriminate normal from abnormal motor skills. Many measures designed by therapists have been poorly developed and lack sound psychometric properties (Benson and Clark, 1982). In contrast, motor measures developed by psychologists and educators, although psychometrically sound, do not incorporate the constructs of motor development that physical and occupational therapists believe are most likely to signal dysfunction. Physical and occupational therapists view these tests as mere checklists of motor development, and question their ability to identify the subtle differences between infants with normal and abnormal motor development. Hence, the inability of these scales to accurately identify motor delays has been attributed to the lack of analysis and description of motor skills. No motor measure has combined adequate psychometric properties with the analysis of the components of motor skills important to therapists. It is reasonable to assume that such a measure, if available, would improve the accuracy of predicting motor outcome.

The second possible explanation for the inaccuracy in prediction of motor function involves the assumption of the neuromaturational theory of motor development used to develop motor scales. A major premise of this theoretical framework is that motor development is primarily organized by the central

nervous system (CNS), and is genetically predetermined. From this perspective, it is assumed that long-term motor abilities can be predicted from the assessment of early motor abilities. For example, using the tenets of the neuromaturational theory of motor development, early delay or deviance in the motor performance of an infant is indicative of CNS damage and will persist as the child ages. This assumption may however be erroneous; abnormal motor skills at an early age may resolve spontaneously just as early deviations in muscle tone resolve (Drillien, 1972). Some types of motor dysfunction, particularly mild and moderate delays, may not be discernible until a certain level of motor skills is achieved or attempted, and hence cannot be detected through the assessment of motor development in early infancy. Finally, factors in the environment may influence motor abilities of infants in either an adverse or beneficial manner. If any of these conditions occur, prediction of long-term motor performance from the observation and assessment of early, evolving motor skills of infants may not be feasible.

1.3.0 Statement of the Problem

When evaluating the predictive abilities of current tests of motor development, it has been difficult to separate the effects of measurement error from an error in the theoretical reasoning that early motor abilities always determine eventual motor abilities. The poor prognostic abilities of infant motor assessments have been attributed generally to the absence of a valid measure of infant motor skills that exhibited both strong psychometric properties and a detailed analysis of the components of motor skills. The expectation has been that prediction of motor dysfunction would improve with the development of such a measure.

The AIMS is a norm-referenced scale that evaluates motor skills from birth to the age of independent walking. The items have been formulated to allow the examiner to assess essential components of motor skills. In addition, the AIMS exhibits excellent inter-rater and test-retest reliability coefficients (Redfern and Maguire, 1994) as well as discriminative abilities (Piper and Darrah, 1994). Thus, if the inability to accurately predict motor function in infants is due to the use of poorly developed measures, the AIMS should fare better than current tools. However, if the poor prediction of motor dysfunction to date is because long-term motor impairment cannot be identified from the characteristics of early motor skills, then the ability of the AIMS to accurately predict motor dysfunction will not be any better than present tests. The ability of the AIMS to predict motor outcome has not yet been investigated.

1.4.0 Objectives of the Study

1. To determine the most accurate cut-off points on the AIMS.

Developers of norm-referenced tests of motor development often suggest using raw scores falling less than or equal to minus 1.5 or minus 2 standard deviations (SD) to identify infants with abnormal motor development, and raw scores falling between minus 1 SD and minus 1.5 SD or minus 2 SD to classify infants with suspicious motor development (Folio and Fewell 1983, Bayley, 1993). These arbitrary cut-offs may not produce the best combination of sensitivity and specificity values. A continuum of cut-off scores on the AIMS was calculated to determine the cut-off points that yielded the most accurate combination of sensitivity, specificity, positive predictive value and negative predictive value in the classification of infants' motor outcome at 18 months adjusted age.

2. To evaluate the assumption that early motor abilities of infants are predictive of later motor abilities.

The predictive abilities of the AIMS were compared to the predictive abilities of two motor assessments currently used by physical therapists: the Movement Assessment of Infants (MAI) (Chandler, Andrews and Swanson, 1980), and the Peabody Developmental Gross Motor Scale (PDGMS) (Folio and Fewell, 1983). If early accurate classification of motor abilities is improved using the AIMS, the present failure to accurately predict motor abilities will be attributed in part to weaknesses in the development of measures of motor development to date, rather than to an incorrect theoretical assumption. However, if the accuracy of prediction obtained from AIMS data is similar to the other two tests (MAI and PDGMS), the theoretical assumption of constancy of development across time may be invalid.

In summary, this study was designed both to contribute to the development of the AIMS by determining the most accurate cut-off points to identify infants with either abnormal or suspicious motor development, and to evaluate the theoretical assumption associated with the prediction of motor development in infancy.

Chapter 2

REVIEW OF THE LITERATURE

2.1.0 Introduction

This chapter reviews the literature in two major areas: screening programs and motor development. General issues of health screening are discussed and applied to screening for children with developmental disorders. The issues involved in screening for motor dysfunction in infants identified as being at risk for future motor problems are then reviewed. Two different theories of motor development, the neuromaturational theory and the dynamic systems theory, are introduced and the feasibility of early screening for motor dysfunction is examined from each of these theoretical perspectives. Differences in the patterns of motor development observed in preterm and full-term infants are also reviewed, and the screening issues associated with these differences are discussed.

2.2.0 General health screening issues

Screening in health is a process to distinguish apparently well persons who probably have a disease from those who probably do not (Mausner and Kramer, 1985). A prevailing assumption that early detection and treatment are always more effective than treatment offered at the usual time of diagnosis has contributed to a proliferation of screening programs for many health conditions (Morrison, 1992). Ideally, the feasibility of screening for a particular disease or condition should be established before the implementation of widespread screening. In reality, this *a priori* evaluation seldom occurs. As a result, "the availability of screening tests and interest in using them has far outstripped our knowledge of their characteristics and value" (Morrison, 1992, p 920).

When evaluating the feasibility of screening for a specific condition, the characteristics of the disorder, the effectiveness of the screening tool used, the effectiveness of the treatment available, and the economics of screening must all be considered (Morrison, 1992). Screening is most effective with conditions that have long pre-clinical phases since the probability of detecting the disorder in these conditions is increased (Friedman, 1994). A longer pre-clinical stage also results in a longer lead time, that is, the interval between detection from screening and the usual time of diagnosis without screening. This lead time represents the extra time gained with screening to treat the disorder. For screening to be justified, the condition must respond positively to early treatment provided during this lead time. If early treatment is ineffective, it could be argued that screening for a disorder is detrimental since it increases the time interval that persons know they are diseased without offering any benefits.

Unfortunately, as health screening programs have increased in number, close evaluation of their effectiveness has not. This lack of good evaluation is due in part to the large sample sizes, time and money required to evaluate most screening programs. Once a screening program has been established, it is extremely difficult to remove the service, even if its merits are unproven.

In terms of the screening tool, the important psychometric property is predictive validity. Predictive validity measures the ability of a test to correctly forecast future behavior (Oyster, Hanten and Llorens, 1987). The test's classification is compared with a later criterion using a gold standard such as x-ray, biopsy, or physical examination. Predictive validity can be evaluated by four properties: sensitivity, specificity, positive predictive value and negative predictive value. Sensitivity refers to the ability of a test to detect individuals

who actually have the disorder, and specificity indicates the ability of a test to detect those individuals who are free of the disorder. Positive predictive value is the proportion of subjects with positive test results who have the target disorder, while negative predictive value is the proportion of individuals with negative test results who do not have the target disorder (Sackett, Haynes and Tugwell, 1985). While ideally all of these properties would yield values close to 100%, in reality this never occurs. Rather, either under-referral of diseased individuals (false negatives) or over-referral of normal individuals (false positives) occurs. High sensitivity is often achieved at the expense of low specificity and vice versa.

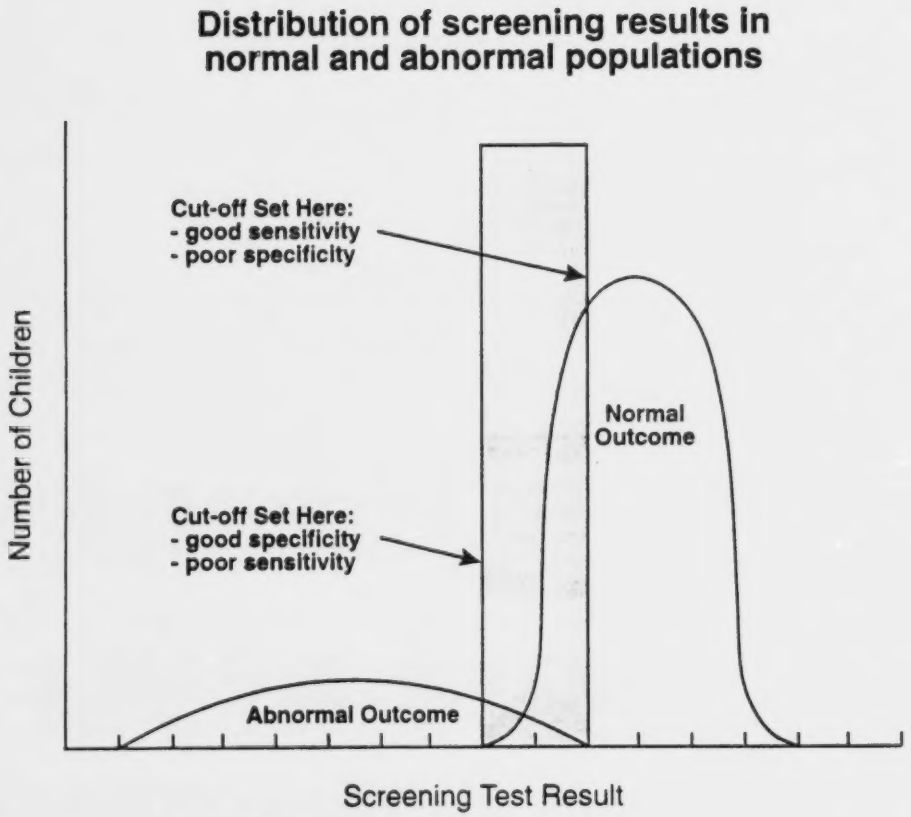
Sensitivity and specificity rates are important for evaluation of screening because they provide an indication of the overall effectiveness of a screening program. However, they do not address the question that is even more important to clinicians and patients: what are the chances that an individual with (or without) a positive test result actually will have (or will not have) the target disorder? Positive predictive and negative predictive values provide the answers to these questions. Predictive values are influenced by the sensitivity and specificity of the screening test and the prevalence of the disorder being screened (Sackett et al., 1985). Disorders with a high prevalence result in higher positive predictive values, and small declines in specificity values result in large declines in the positive predictive values. One per cent has been suggested as a minimum prevalence rate to justify screening (Kappy, 1976), except in conditions such as phenylketonuria where a cure is readily available and the consequences of not screening are catastrophic. Mausner and Kramer (1985) propose that it is only when the prevalence of the disorder in the

screening group reaches 15% to 20% that a respectable positive predictive value is possible; in their example 'respectable' represented a positive predictive value of 75% to 80%.

The values of all four properties are affected by the cut-off scores chosen to classify subjects as abnormal (Figure 2.1). Raising the threshold for considering a case to be positive will result in higher specificity values (fewer false positives) but a loss of sensitivity (more false negatives). On the other hand, lowering the threshold for considering a result to be positive typically will increase the sensitivity (reduce false negatives) but decrease the specificity (increase false positives) (Greenberg, 1993). Choices involving cut-off points and the best combination of sensitivity and specificity values must take into consideration the availability of an effective treatment and the consequences of both types of mislabelling. If it is important not to miss a condition which is both treatable and serious, then high values of sensitivity are most important. On the other hand, if detecting a disease results in little benefit while falsely labelling normal persons as sick leads to increased worry and cost, then high specificity values are preferred (Friedman, 1994). Because all of these points need to be taken into consideration, the 'best' combination of values for sensitivity and specificity varies for each disorder.

Careful evaluation of optimal cut-off scores does not always occur in screening programs. Normal, suspicious and abnormal classifications have often been determined by assuming a normal or Gaussian distribution, and utilizing minus one and minus two standard deviations as cut-off scores for delineating 'suspicious' and 'abnormal' classifications (Anderson, 1990; Elveback, Guiller and Keating, 1970). This practice, traditionally used in

Figure 2.1



Adapted from Mausner and Kramer, 1985, p 219

psychological testing, has been extrapolated into health screening and is unsatisfactory for two reasons. First, it assumes that the range of values obtained on a screening test are normally distributed; this condition is not always met in health conditions (Anderson, 1990). Second, it implies that the prevalence of the disorder screened is approximately 2%, (<-2SD); an assumption seldom confirmed. Using a normative distribution curve for cut-offs, 'normal' means 'usual' score. The use of 'normal' in this context should not be confused with 'healthy'. Indeed, there are many examples in health care of values falling within 'normal' ranges that are not indicative of 'healthy' values (Friedman, 1994).

The use of cut-off scores will never be entirely satisfactory because few diseases can arbitrarily be classified into a 'normal/abnormal' dichotomy. In reality, a continuum of severity exists with most medical conditions; 'normal' gradually shifts to pathological. In general, the more severe the condition in an individual, the easier it is to classify the individual case correctly as 'abnormal'. Individuals with less severe test results or physical signs of the disorder are more difficult to classify accurately. The consequences of both under- and over-referral, the resources available, and the effectiveness of the intervention available must all be considered when determining cut-off points to delineate normal from abnormal.

In addition to the psychometric qualities described above, an effective screening tool must also be acceptable to the screened population (Beaglehole, Bonita and Kjellstrom, 1993). To meet this criterion the screening tool must be quick, easy to administer, easily accessed and non-invasive. If these conditions are not met, even the most valid screening tool will not be

effective because it will not be used.

Finally, the economic feasibility of screening cannot be ignored. The total cost of screening, including the screening procedure, diagnostic evaluation and early treatment, must not outweigh the cost of the disease without screening (Stangler, Huber and Routh, 1980).

2.2.1 Screening children for developmental disorders

The concept of screening for developmental disorders has been part of the medical model for the last six decades (Gesell, 1934). Gesell (1938, p 225) emphasized that "where there is lawfulness there is potential prediction", and believed that the pattern of motor behaviors observed in developing children were dependent on the central nervous system maturing in an orderly and constant fashion. Advocates of early screening adhere to this assumption of the constancy of the sequence and rate of motor development. Interest in screening for developmental disorders in young children increased dramatically in the United States since the passage of the The Education of All Handicapped Children Act Amendments of 1986 (Public Law 99-457), now part of the Individuals with Disabilities and Education Act (1991). This law mandates a "statewide, comprehensive program of early intervention services for all handicapped infants and their families" (Shonkoff and Meisels, 1990, p 19), and demands early identification of developmental disorders to allow for the implementation of early intervention. Each state must develop its own definition of developmental delay, based on appropriate diagnostic procedures in five areas of performance: cognitive, physical, language and speech, self-help, and psychosocial development. Accurate screening for these disorders is essential in order to provide early intervention to the appropriate children.

The literature suggests that screening for early developmental delay is not yet effective. Meisels and Margolis (1988) compared the age of diagnosis and treatment for a group of developmentally disabled children who had received screening with a similar group of disabled children who had not received screening. They reported no difference between the groups in the age of diagnosis or initiation of treatment, and recommended further evaluation of developmental screening programs. Meisels (1989) reviewed the effectiveness of the Denver Development Screening Test (DDST) (Frankenburg, Dodds and Fandal, 1970); he reported unacceptably high rates of false negative results and recommended that the use of the DDST for screening be re-evaluated. In contrast, Glascoe et al. (1992) studied the accuracy of the revised Denver II (Frankenburg et al.,1990), and reported an acceptable sensitivity rate of 83%, but low specificity (43%) with a high rate of false positive identification.

Concerns and doubts regarding the feasibility of mass developmental screening programs have led to the exploration of alternate methods for detection of developmental disabilities. One suggestion is developmental surveillance, a process of observing the development of children and the reactions of their parents in a longitudinal, flexible way. Parents are encouraged to be active participants in the surveillance process and input is received from a variety of sources, including preschool teachers and public health nurses (Dworkin, 1989). This method of detection is more evaluative than predictive since it chronicles the changes in a child's development over time. Indeed most pediatricians tend to rely on clinical impressions rather than standardized tests because they find screening tests too long and complicated (Glascoe and Dworkin, 1993).

A criticism of developmental screening tools is their eclectic nature. McCall (1983) suggested that screening tests should become more syndrome specific, with specific items to detect motor dysfunction. This concept of specific tests for specific dysfunction has led to the construction of specialized measurement tools, including measures of motor function. The availability of such tests, coupled with the increased survival rate of preterm infants who are known to be at risk for motor dysfunction, has spawned yet another screening program: the early identification of neuromotor dysfunction in at-risk children.

2.2.2 Screening for neuromotor dysfunction in at-risk infants

Preterm infants are known to be at increased risk for motor dysfunction. Although low birthweight infants comprise only 6% of live births, infants who weigh less than 2500 grams account for about one third of all babies who later have signs of cerebral palsy (Kuban and Leviton, 1994). Infants who weigh less than 1500 grams at birth have a rate of cerebral palsy 25 to 31 times higher than full-sized newborns, with the risk increasing as birthweight decreases (Stanley, 1992). The incidence of severe motor dysfunction in infants weighing less than 1500 grams is estimated at 15%, and the incidence of infants demonstrating mild to moderate motor dysfunction is 15% to 25% (Bennett, 1988; Coolman et al.,1985). This second group of infants is often referred to as 'suspicious' in their motor development; although they demonstrate mild motor delay or mild abnormal physical signs, the long-term significance of these early motor signs is unclear. The results of studies evaluating the predictive abilities of motor assessment tools have been disappointing with this group of infants.

Investigators evaluating the ability of tests of motor behaviors during the neonatal period to predict motor outcome of preterm infants all report high false

positive and low specificity rates. Dubowitz et al. (1984) compared the neonatal ultrasound scans and term neurological assessments of 129 preterm infants to their developmental assessments at 12 months adjusted age. Stewart, Hope et al. (1988) examined the relationship of ultrasound scans and neonatal assessments of 111 preterm infants with their developmental outcome at 12 months adjusted age. Allen and Capute (1989) assessed 210 high-risk preterm infants before 44 weeks postconceptional age and compared these scores with developmental outcome between 1 and 5 years of age. Touwen (1990), using a sample of 47 preterm infants, evaluated the relationships between types of infant movements at 33 to 36 weeks postconceptional age, neurological assessment at 40 weeks postconceptional age (term), and developmental follow-up examinations. Finally, Bozynski et al. (1993) examined the predictive abilities of cranial ultrasound and a neurological examination at 40 weeks postconceptional age in 47 preterm infants. All five studies reported similar results; infants who were classified as normal in the neonatal period were likely to remain normal, but many of the infants classified as abnormal from the neonatal motor assessments were later classified as developing normally. The neonatal assessments correctly identified infants with eventual motor problems, but at the expense of incorrectly labelling many normally developing infants as exhibiting abnormal motor development. The consequences of over-identification must be considered. False positive identification of normally developing infants as suspicious or abnormal could alter the attitudes and expectations of parents and teachers toward a child (Cadman et al., 1987), and increase parental anxiety (Fyro and Bodegard, 1987).

Interest in early prediction of motor dysfunction continues into the first

year of life. Typically at-risk infants are assessed at neonatal follow-up clinics. The majority of infants attending these clinics are preterm infants, but full-term infants with adverse perinatal histories are also seen. Physical and occupational therapists often administer the motor tests at these clinics, and the predictive abilities of infant motor measures used by these therapists have been investigated. Two tests commonly used by physical and occupational therapists to assess infant motor development are the Peabody Developmental Motor Scales (PDMS) (Folio and Fewell, 1983), and the Movement Assessment of Infants (MAI) (Chandler et al., 1980). The predictive abilities of these two measures have been evaluated.

Palisano (1986) compared the predictive validities of the Peabody Developmental Gross and Fine Motor Scales and the Psychomotor Developmental Index (PDI), the motor scale of the original Bayley Scales of Infant Development (Bayley, 1969). He assessed 23 full-term and 21 preterm infants on both scales at 12, 15, and 18 months. The correlations between 12-month scores and 18-month scores on both the PDI and the Peabody Developmental Scales were poor for preterm infants, and Palisano cautioned against use of either motor measure as a predictive tool.

Four month risk scores on the MAI have been correlated with later developmental outcome. Using a total risk score on the MAI of 8 or greater as a cut-off for abnormal classification, Deitz, Crowe and Harris (1987) reported no significant correlations between the MAI scores of 77 at-risk infants, and their scores on either the PDMS or the Frostig Eye Motor Co-ordination Subtest (Frostig et al., 1964) at 4.5 years of age. In contrast, Harris et al. (1984) using retrospective data on 246 preterm infants, calculated the correlation of the same

4 month cut-off score on the MAI and 1 and 2 year PDI scores, and reported significant Pearson correlations ($p < 0.01$). While the correlation coefficients were significant, the magnitudes were low (0.36 and 0.37), raising the question of clinical significance.

Three studies (Harris, 1987; Harris, 1989; Paban and Piper, 1987) evaluated the sensitivity and specificity rates obtained using the MAI and reported similar findings. A four month MAI total risk score of 8 or greater as a cut-off resulted in acceptable sensitivity but poor specificity rates; many infants who were classified as abnormal/suspicious at four months adjusted age were deemed normal at a later age.

Swanson et al. (1992) investigated the ability of the MAI to predict the neuromotor outcome of 160 low birthweight infants, using a revised cut-off score of greater than 9 risk points at four and eight months adjusted ages. Again, sensitivity rates were better than specificity rates at both ages, with the absolute values dependent on the placement of the 'suspicious' category of infants into either the 'normal' or 'abnormal' categories. Because of the difficulty in identifying infants in the suspicious category, inclusion of their scores with the abnormal category lowers the sensitivity rate, and inclusion of their data in the normal category lowers the specificity rate. The authors attributed the high false positive rates to transient neuromotor abnormalities and immaturity of motor function in low birthweight infants.

Piper et al. (1992) assessed the sensitivity and specificity of varying cut-off scores on the MAI using data collected on 75 preterm infants at four months chronological and adjusted ages. They concluded that the optimal combination of sensitivity, specificity, and predictive values varies according to the age of the

infant, the cut-off score chosen, and the severity level of the predicted disorder. If the target for prediction is only neurologically abnormal infants, then a higher total risk score must be used as a cut-off value than if the targeted population is identification of both neurologically abnormal and suspicious infants. In this study, the specificity rates were usually higher than the sensitivity rates.

Which value is more important in screening for motor dysfunction in infants, specificity or sensitivity? The screening literature suggests that if a condition is treatable, then high sensitivity values are important in order to offer an effective treatment to all persons. Conversely, if an effective treatment is not available, and there are consequences to false positive identification, then high specificity values should be targeted. The evidence for efficacy of early physical therapy intervention with children with a diagnosis of cerebral palsy is poor (Palmer et al., 1988; Campbell, 1990), suggesting that the aim of screening tests for motor dysfunction should be acceptable specificity values. Allen and Alexander (1994) argued for valuing specificity over sensitivity values since false positive results overwhelm community resources and increase parents' concerns about their infants' development. In contrast, proponents of early identification of all infants with a disability contend that early identification and intervention will assist families in coping with a child with a disability, reduce secondary complications and help children reach their maximum potential (Wolery, 1989). These arguments support the goal of high sensitivity rates. Clearly the issue remains unresolved in screening for motor dysfunction in infants.

The format of the items on the PDMS and the MAI may contribute to their poor predictive abilities. The Peabody Developmental Motor Scale was

developed by educators to identify children whose gross and fine motor skills are delayed or aberrant relative to a normative group. The criteria for success of many items on the gross motor scale incorporate timing of a specific skill or position and distance travelled rather than describing the qualitative aspects of motor skills that physical and occupational therapists use to assess motor skills. The MAI, although providing rich descriptions for each item, divides motor skills into components of movement such as muscle tone, reflexes and automatic reactions, and requires assessment of each component in isolation. This approach entails a great amount of handling of the infant, and does not encourage the assessment of motor abilities in a functional, holistic context. Neither measure provides a detailed analysis of motor skills in a functional context.

The inability of current infant motor assessment tools to successfully predict high-risk infants' motor outcome at an early age is discouraging. If failure to predict motor outcome is due to ineffective measurement tools, it is logical to assume that a well-developed, psychometrically sound motor tool, incorporating constructs of motor development familiar to physical and occupational therapists, should improve predictive validity of early motor assessment.

The AIMS represents a new measure of motor development that incorporates psychometric properties with descriptive analyses of the components of motor skills. Development of the AIMS included close collaboration with physical and occupational therapists at all stages of item generation and selection (Piper et al., 1992). The AIMS is designed to measure motor skills from 40 weeks postconception to independent walking. It contains

58 items divided into four subscales: prone (21 items), supine (9 items), sit (12 items), and stand (16 items). Each item is specifically described in terms of the weightbearing surface of the body, the posture necessary to achieve the skill, and the antigravity or voluntary movement performed by the infant in the position. This format for analysing motor development is used clinically by therapists to identify the components of a movement skill that are difficult for an infant to perform. The AIMS assessment is observational with minimal handling of the infant.

The psychometric properties of the AIMS were stringently evaluated (Redfern and Maguire, 1994). Test-retest and inter-rater reliability coefficients range from 0.85 to 0.99 when evaluated in age groupings of one month. Concurrent validity of AIMS raw scores with the Peabody Developmental Motor Scales' gross motor raw scores and raw scores of the motor scale of the Bayley Scales of Infant Development yielded correlation coefficients ranging from 0.84 to 0.98 for age groupings of 5 month intervals. In addition, multidimensional scaling methods indicated the scale represents only one construct of development, motor maturity. Thus, in addition to providing a comprehensive description of each motor skill, the AIMS exhibits properties of a reliable instrument for measuring infant motor development. If early prediction of eventual motor outcome is feasible, the characteristics of the AIMS make it a likely candidate for success.

2.3.0 Theories of motor development

The rationale for early screening for neuromotor dysfunction is based on the assumption that early developmental status predicts long-term developmental outcome. This assumption arises from the neuromaturational

theory of motor development (Gesell, 1928; McGraw, 1945). The main tenet of the neuromaturational theory proposes that the attainment of gross motor skills is dependent solely on the neurological maturation of the CNS. Environmental influences, if any, are temporary and transient, and major perturbations are required to effect any change in the preprogrammed pattern and rate of motor development. This theory purports an orderly and invariant 'unfolding' of motor skills with only minor individual variations in rates of skill acquisition. Four classic studies of motor development (Ames, 1937; Gesell and Ames, 1940; McGraw, 1945; Shirley, 1931) support the sequential appearance of motor abilities, and provide the theoretical basis for the widespread use of motor development scales to evaluate and to predict infants' motor performance. Developmental scales such as the Bayley Scales of Infant Development and the PDGMS are based on this theoretical framework.

Within this prescriptive CNS controlled framework of motor development, an early delay or deviance in motor abilities is interpreted as a sign of permanent CNS pathology. The assumption that early motor delays portend future motor dysfunction has resulted in the current interest in evaluating early motor development as a predictor of neuromotor problems in selected at-risk infants. This assumption may be erroneous because the rate and quality of motor development may be non-linear, with periods when no new motor skills emerge, and other periods when many new motor skills simultaneously emerge. Minor neurological deviances may be 'self-righting' (Fetters, 1991), with spontaneous recovery of function, or early motor development may be temporarily influenced by environmental events occurring in infancy. Flavell (1972) argued that different orders of behaviors can emerge as a result of

several different developmental processes, and that the structure of the organism, the structure of the environment, and the structure of the behavioral items to be mastered were three factors that together helped determine the form and rate of a particular sequence. This point of view of development is more in accordance with dynamic systems theory, a new theory of motor development emerging from the psychological literature.

The dynamic systems theory of motor development (Horak, 1992; Kamm, Thelen and Jensen, 1990; Thelen, 1989; Thelen, 1987) proposes that the neurological system is only one of many systems contributing simultaneously to the motor abilities of infants. Other systems influencing motor abilities are physical factors (head size, muscle strength, etc.), cognitive abilities, the environment, and the task initiating the motor skill. All of these subsystems are thought to influence the performance of a motor skill. This assumption implies that changes in any one subsystem can affect the performance of motor skills, and that performance is not solely dependent on the CNS. The premises of the dynamic systems theory suggest that the environment plays an important role in influencing the motor abilities of infants.

The dynamic systems theory also suggests that motor development is non-linear; small but critical changes in one subsystem can result in large behavioral changes in motor skills. Thus, infants may be delayed in their motor skills but, as the interaction of the subsystems changes slightly, they are capable of spontaneously 'catching up' in their motor development. This assumption supports the concept of developmental surveillance and ongoing evaluation rather than prediction. Because of the continual interaction and influence of many subsystems, including the environment, the dynamic systems

theory of motor development does not support the idea that early motor delays can be used to predict later motor dysfunction.

The neuromaturational theory and the dynamic systems theory explain motor development from different perspectives. Preterm infants are known to demonstrate certain motor strategies that differ from those observed in full-term infants. Using the assumptions of the two motor theories, different conclusions about the implications of these motor differences can be made.

2.3.1 Preterm motor development

Differences in the motor development of preterm infants compared to full-term infants have been well documented The most frequently cited differences are that preterm infants demonstrate less flexor muscle tone (Ferrari, Grosoli, Fontana, and Cavazzuti, 1983; Forslund and Bjerre, 1983; Stjernqvist and Svenningsen, 1990), more extended postures (Gorga, Stern and Ross, 1985; McGrew,Catlin & Bridgford, 1985; Touwen and Hadders-Algra, 1983), prolonged retention of primitive reflexes (Burns and Bullock, 1980; Marquis, Ruiz, Lundy, and Dillard, 1984) and more variable (de Groot, van de Hoek, Hopkins and Touwen, 1992; Gorga, Stern, Ross and Nagler, 1991) or different patterns (Mandich, Simons, Ritchie, Schmidt and Mullet, 1994) of motor development. In reviewing the literature Bartlett and Piper (1993) concluded that despite methodological issues such as non-homogeneous groups, preterm infants do develop in a different manner from full-term infants.

Differences in the evolution of motor skills observed in preterm infants may adversely effect the success of screening tools that are constructed using the motor behaviors of full-term infants as a model. In particular, transient dystonia, a syndrome of transiently abnormal neurologic signs observed in

preterm infants, may contribute to the high rate of false positive identification of motor dysfunction in preterm infants during the first year of life. Transient dystonia was first described by Drillien (1972) who identified neuromotor abnormalities observed during the first few months of life in 40% to 50% of low birthweight infants. Signs included extensor posturing, increased adductor tone in the legs, persistence or exaggeration of primitive reflexes, and poor postural control. Subsequent follow-up revealed that these deviant signs gradually resolved by 8 to 12 months of age in 60% of the infants. Other studies have supported these findings, although the age of documented resolution varies in the studies (Hack, Caron, Rivers and Fanaroff, 1983; Piper, Mazer, Silver, and Ramsay, 1988; Tudehope, Burns, O'Callaghan, and Mohay, 1981). The long-term implications of transient symptomatology remain unclear. The results of some long-term follow-up studies have suggested that children with transient dystonia are at increased risk for later learning problems (Drillien, Thomson and Burgoyne, 1980) or other 'soft' neurological problems (Burns, Mohay and Croker, 1987; Nelson and Ellenberg,1982; Vohr and Coll, 1985). Other investigators have reported no relationship between transient symptomatology and later neuromotor or cognitive abilities (D'Eugenio, Slagle, Mettelman and Gross, 1993; Li, Sauve and Creighton, 1990; Stewart, Deitz, Crowe, Robinson and Bennett, 1988). Results vary depending on the criteria used to define transient symptomatology, the severity of the symptoms, and the age of follow-up. Gorga, Stern, Ross and Nagler (1991) have suggested that increased frequencies of 'suspect' or 'abnormal' outcomes in an infant are more predictive of poor outcome at 3 years of age than single variations in classification from normal to suspicious.

In terms of accuracy of screening programs, transient symptomatology has been suggested as a reason for the high rate of false positive identification of motor dysfunction in preterm infants in the first year of life (Nelson and Ellenberg, 1982; Swanson et al., 1992). It could be that motor tests that evaluate discrete neurological signs such as muscle tone and primitive reflexes are more likely to identify infants with transient symptomatology than tools that document more integrated motor skills. If this premise is true, then a scale such as the MAI, that specifically tests signs of transient symptomatology such as muscle tone and primitive reflexes, would provide poorer specificity rates than a test based primarily on motor skill attainment. Transient symptomatology represents a dilemma for screening for motor dysfunction, primarily because the long-term implications of the disorder are still unresolved. Should these children be identified or not? Considering that there is no evidence that early intervention is effective with these infants with motor dysfunction (Piper et al., 1986; Rothberg, Goodman, Jacklin and Cooper, 1991) it could be argued that screening for the disorder is not beneficial. The clinical interpretations and importance of transient symptomatology are influenced by the theoretical framework of motor development chosen to explain the evolution of motor skills.

From the perspective of the neuromaturational framework, differences in motor development observed in preterm infants compared to full-term infants are viewed as indicators of permanent CNS pathology. Transient symptomatology is regarded as an indicator or precursor of future neurological dysfunction. From a dynamic systems perspective, the differences in motor development observed in preterm infants can be explained not only by neurological causes, but by the interaction between the environment and many

developing subsystems in infants including, but not restricted to, the CNS. For example, one of the reasons recently proposed to explain differences in muscle power and posturing observed in preterm infants is the long period of time the infants remained in the supine position in the neonatal intensive care units (de Groot et al., 1992). The authors suggested that the prolonged contact of the trunk and neck muscles with the surface of the bed contributed to an overstimulation of the skin overlying these muscles and resulted in an overactivation of the nerves to these muscles. Their solution to the problem was to modify the environment by changing the position of the infant. This study exemplifies how a system other than the CNS can be identified as the cause of the extended postures, and how a solution was offered by changing the environmental conditions. This perspective recognizes that environmental and physical influences, not neurological integrity, may account for the unique characteristics of pretem infants' motor development.

2.3.2 Relationship of motor theories and screening assumptions

As described in chapter 1, early screening for motor dysfunction is justified if two assumptions are met. First, a strong positive relationship must exist between early motor abilities and the eventual motor abilities of the infant. If this is not the case too many infants will be misclassified as either having a motor problem when none exists, or being normal when in fact they eventually present with motor dysfunction. Second, for screening to be warranted, it must be assumed that early treatment is indeed beneficial and has a positive impact on the disorder.

The neuromaturational theory, with its emphasis on movement controlled primarily by the CNS, suggests that children with early motor dysfunction will

exhibit permanent motor dysfunction. Thus this theory supports the first assumption of screening. The second assumption of screening, the benefit of early treatment, is not well supported by the neuromaturational theory. Since this theoretical framework purports that movement is pre-programmed and controlled by the CNS, treatment based on environmental interventions would have little, if any, effect on motor development. Physical therapy and occupational therapy treatment strategies attempt to change infants' motor abilities by augmenting the infants' physical abilities and by modulating the environment. Neither of these concepts align with the neuromaturational model of hierarchical control by the CNS.

In contrast, the tenets of the dynamic systems theory suggest that future motor abilities cannot be predicted from a delay in early motor abilities because opportunities exist to change any one of the myriad of interacting subsystems, and thus effect the motor behaviors 'en route'. While early prediction is not supported, the assumption that early treatment can change motor behaviors is feasible due to the emphasis on the importance of environmental factors and other factors within the infant.

As shown in Table 2.1, each theory supports one of the two assumptions fundamental for screening. Unfortunately, neither theoretical framework supports both assumptions. The second assumption of screening pertaining to the benefits of early treatment cannot be evaluated well until it is determined whether the first assumption is affirmed. This study attempted to evaluate the first assumption, that later motor abilities can indeed be predicted from early motor abilities.

Table 2.1

Relationship between Screening Assumptions and Motor Theories

	Motor Theory	
	Neuromaturational	Dynamic Systems
Screening Assumption		
Early Identification	Supported	Not supported
Early Treatment	Not supported	Supported

2.4.0 Summary of literature review

(i) To evaluate a health screening program, the characteristics of the disorder, the effectiveness of the screening tool, the effectiveness of the available treatment, the acceptability of the screening program, and the economics of screening must all be considered.

(ii) When determining the most appropriate cut-offs to use on a screening tool, the values of sensitivity, specificity, positive predictive value, and negative predictive value must all be considered in combination. The traditional cut-offs of minus one and minus two standard deviations may not represent the best cut-offs for all screening tools.

(iii) Screening programs designed to identify infants with motor dysfunction from a population of at-risk infants in the neonatal period or early infancy most often result in high false positive rates of identification.

(iv) Screening for motor dysfunction in infancy assumes a linear model of motor development, and is supported by the neuromaturational model of motor development. In contrast, the dynamic systems theory of motor development suggests that early prediction of eventual motor abilities is not feasible.

(v) The motor development of preterm infants exhibits a different pattern than the motor development of full-term infants. The significance of these differences on subsequent motor development is dependent on the theoretical framework of motor development used to explain motor development.

Chapter 3

METHOD

3.1.0 Objectives

The two main objectives of this study were to determine the appropriate percentile ranks on the AIMS to use as cut-off points to identify infants with abnormal and suspicious motor development, and to evaluate the assumption that the early motor development of infants is predictive of later motor skills.

3.2.0 Design

A prospective, longitudinal design was used; infants were recruited during their hospital stay in the neonatal intensive care units and their gross motor development was assessed at three ages: 4, 8, and 18 months. The ages of all preterm infants were corrected for prematurity. A longitudinal design was necessary in order to determine the eventual motor status of infants assessed in infancy.

3.3.0 Sample

The target population was at-risk infants who are cared for in neonatal intensive care units. The study population was comprised of infants admitted to the two tertiary neonatal intensive care units in Edmonton at the University of Alberta Hospitals and at the Royal Alexandra Hospital during 1992 to 1994. Both preterm and full-term infants were included in the study population. Any infant whose birthweight was less than or equal to 1500 grams was eligible for inclusion. Preterm infants weighing more than 1500 grams who had a history of intraventricular hemorrhage Grade III or IV, identified by ultrasound assessment, were also included given their increased risk of motor dysfunction (Bozynski et al., 1988). Full-term infants with hypoxic ischemic encephalopathy (HIE) Stage II

and III by Sarnat scoring (Sarnat and Sarnat, 1976) were eligible for inclusion since infants with HIE of this grading are known to have a high risk of motor handicap (Robertson and Finer, 1993). Infants with congenital anomalies were excluded from the study since these infants' problems can be identified at birth.

Two nurses were employed, one at each hospital, to identify infants eligible for the study. These nurses obtained informed consent (Appendix A) from the parents of each infant before he/she was discharged from the hospital.

The sample size was estimated based on a prevalence rate of motor dysfunction in at-risk infants of 10% to 20%. The reported prevalence of major handicap in very low birth weight infants varies: Ornstein, Ohlsson, Edmonds and Asztalos (1991) reported an overall major handicap rate of 6% to 12%t in their review article describing the outcome of very low birthweight infants while Saigal (1995), in her review article cited prevalence rates of neurosensory impairments of 17% to 24% for infants less than 1000 grams, and 5% to 12% for infants between 1000 and 1500 grams.

Using plus or minus 5% as the acceptable level of uncertainty and a prevalence rate of 15%, the sample size necessary was calculated from the formula $m \geq (1-\theta)/\theta A^2$ where θ equals the population prevalence rate, and A represents the acceptable coefficient of variation (Bay, 1990). A was calculated using a probability level of 0.05 and a prevalence rate of 0.15 (A = 0.025/0.15 = 0.17). Thus, the estimated sample size if the margin of error is within plus or minus 5% for 19 times out of 20 is $0.85/0.15(0.17)^2 = 212$ infants.

3.4.0 Data collection

An infant's medical status in the perinatal period is considered to influence outcome (Brazy et al., 1991; Korner et al., 1993). For this reason, information on

the following perinatal variables were collected to evaluate their effects on eventual motor outcome: Apgar score at 1 minute (APGAR1), Apgar score at 5 minutes (APGAR5), number of days in hospital (DAYSIN), number of days on oxygen, including assisted ventilation and nasal prongs (VENT), presence or absence of seizures, confirmed by electroencephalogram (SEIZURES), presence or absence of periventricular leukomalacia (PVL), presence or absence of bronchopulmonary dysplasia (BPD), absence or grade of intraventricular hemorrhage (IVH), absence or Sarnat grading of hypoxic ischemic encephalopathy (HIE), and appropriate or small for gestational age (SIZE). This information was extracted from the infants' hospital records by the project coordinator.

Three motor measurement tools were administered at 4 and 8 months: the MAI, the PDGMS, and the AIMS. The MAI is a standardized, criterion-referenced assessment tool developed by physical and occupational therapists (Chandler et al., 1980). The MAI contains a total of 65 items divided into four subscales: muscle tone and posture, primitive reflexes, automatic reactions, and volitional movement. Items in the muscle tone section are scored on a 6-point, bidirectional scale to indicate hypotonic, normal and hypertonic muscle tone. Items in the other three subsections are scored on a 4-point unidirectional scale, with 1 representing the most mature response. The authors have developed 4 and 8 month risk profiles that indicate scores considered to be deviant for each item. Risk points are summed to yield a total risk score (TRS), which forms the basis of evaluation and comparison. No norms are available.

The PDGMS is a standardized assessment tool that evaluates gross motor development of children between zero and 83 months of age (Folio and

Fewell, 1983). It consists of 170 items divided into 17 age level items and covers 5 motor domains: reflexes, balance, non-locomotor mobility, locomotion, and receipt and propulsion (ability to catch and throw). Items are scored on a 3-point ordinal scale: 0=unsuccessful, 1=skill emerging, but criterion not fully met, and 2=successful performance. Norms were generated using 617 children stratified on geographical region of the U.S., race, sex and age. Raw scores may be converted into age equivalent scores, developmental quotients, and percentile ranks.

The AIMS is a measure of infant gross motor development from birth to 18 months and has been described previously (section 2.2.2, p. 20). Items on the AIMS are scored as 'observed' or 'not observed'. Subscale scores for each of the four subscales, prone, supine, sit and stand, are summed to yield a total score. Normative data were collected on 2202 infants representative of infants born in the province of Alberta between March 1990 and June 1992. The normative sample, randomly selected by birthdates from records in the Department of Vital Statistics, is comprised primarily of normally developing full-term infants. However, by random selection 120 preterm infants (5.4%) were included in the sample. The sample also included infants with a diagnosis of Down Syndrome (n=1), spina bifida (n=2), blindness (n=5), and congenital heart defects (n=8). These infants were included in the normative data in order to obtain a true representation of all infants rather than only normally developing full-term infants.

The total raw score of the AIMS is plotted on a percentile rank graph to provide an estimate of the infant's performance compared to his or her age-matched peers in the normative sample. Descriptions of each measure and item samples are provided in Appendix B.

One of two pediatric physical therapists assessed each infant on all three tests at 4 and 8 months adjusted ages. In most cases, the same assessor evaluated an infant at both 4 and 8 months. Both therapists have extensive experience assessing the motor development of infants, and were familiar with the administration of all three measures. All infants were seen within one week of 4 and 8 months adjusted ages, thus fulfilling the administration requirement of the MAI. Both assessors were unaware of the infants' medical histories, including gestational age, and the presence or absence of any risk factors. Inter-rater reliability checks were conducted throughout the study; the intra-class reliability coefficients (ICC 1,1) (Shrout and Fleiss, 1979) are presented for each test in Table 3.1.

The measures were administered simultaneously as much as possible. An infant's spontaneous movements were first observed, and then specific items on the MAI and PDGMS were performed. The average time to administer all three assessments was 30 to 45 minutes.

A developmental pediatrician assessed each infant at 18 months adjusted age to determine classification of final motor outcome. His assessment included an evaluation of posture, oral motor control, strabismus, muscle tone, evolution of milestones, and reflexes as described by Levine (1980). From the results of this assessment, each infant's motor abilities were classified as normal, suspicious, or abnormal. The suspicious classification included infants who demonstrated one or more of the following criteria: 1) not yet walking, 2) asymmetry, 3) retention of primitive reflexes, 4) isolated toe walking without evidence of increased deep tendon reflexes, 5) walking with a wide base of support, 6) severely pronated feet, 7) muscle weakness. Infants were classified

Table 3.1

Inter-tester Reliability (n=12)

Test	Intra-Class Coefficients (1,1)
AIMS	0.98
MAI	0.99
PDGMS	0.93

as abnormal if they displayed abnormal muscle tone (either hypotonia or hypertonia), absent or increased deep tendon reflexes, retention of primitive reflexes, and/or significantly delayed milestones.

In addition to the motor assessment and classification at 18 months adjusted ages, the pediatrician also scored the motor performance of each infant on the Motor Scale of the Bayley Scales of Infant Motor Development, second edition (BSID II) (Bayley, 1993). The motor scale of the BSID II contains 111 items and evaluates the fine and gross motor abilities of infants from one month to 42 months of age. Performance is tested from an individual's basal level to ceiling level. The BSID II is frequently used in studies of infant motor development, and has been normed on a representative sample of 1700 infants in the United States.

3.5.0 Data analyses

The data were analyzed by three methods. First, sensitivity, specificity, positive predictive and negative predictive values were calculated. Second, a series of discriminant function analyses were done using different predictor variables. Finally, correlations between the three motor measures and outcome at 18 months on the Motor Scale of the BSID II were evaluated.

3.5.1 Sensitivity, specificity, positive and negative predictive values

In order to construct two by two tables to calculate sensitivity, specificity, and positive and negative predictive values, the three outcome categories at 18 months adjusted age, normal, suspicious, and abnormal, were organized into dichotomous data. While normal and abnormal outcomes are well defined categories, infants in the suspicious classification are difficult to place into a dichotomous organization of outcome (Piper, Darrah, Pinnell, Byrne and Watt,

1991). The suspicious group of infants was analyzed two ways: first they were combined with the group of infants classified as normal, and second with the group of infants classified as abnormal. Using this strategy, each motor measure was evaluated both on its ability to detect infants with abnormal motor development, and its ability to identify infants with abnormal or suspicious motor development.

On the MAI, two cut-off points were used. Piper et al. (1991) evaluated various cut-off points on the MAI at 4 months adjusted age, and they recommended that for the detection of neurologically abnormal infants, the optimal cut-off score was a total risk score greater than 9, and for the detection of the both neurologically abnormal and suspicious infants, the optimal cu-toff score was a total risk score greater than 4. The authors of the MAI also recommended a cut-off score of greater than 9 risk points to delineate an infant at risk for motor problems (Swanson et al., 1992). This cut-off score of greater than 9 risk points is based on data derived from the normal range of scores for term and preterm infants, and represents a total MAI risk score one standard deviation above the mean for healthy low birthweight infants at both 4 and 8 months (mean = 6, standard deviation = 3). Values were calculated using both cut-off values: 4 and 9, at ages 4 and 8 months, and for both classification schemes.

The interpretation guidelines for the PDGMS suggest that if a child's z-score is equal to or greater than plus 1.0 or equal to or less than minus 1.0, the performance of the infant is different from the mean of the norming population. If the z-score is plus 1.5 or greater or minus 1.5 or less, the difference is considered to be significant. Thus, z-scores of minus 1 and minus 1.5 were used to identify infants with suspicious and abnormal motor development. These z-

scores correspond to the 16th and 6th percentile ranks respectively with a normal distribution. In addition, the predictive values using a cut-off score of less than or equal to a z-score of less than minus 2 (2nd percentile) were also calculated.

On the AIMS, the sensitivity, specificity, positive predictive values and negative predictive values were calculated for percentile ranks from 0 to the 25th percentile inclusive. The cut-off scores providing the optimal combinations of the four values on the AIMS were then selected.

3.5.2 Discriminant function analyses

Discriminant function analyses allowed the evaluation of the classification abilities of the three assessment measures in three rather than two classification categories, thus permitting the classification of suspicious infants as a distinct group. These analyses also removed the constraint of predetermined cut-off points on the MAI and the PDGMS. Finally, by examining the weighting, or the standardized coefficients assigned to the subscales of the three measures, the relative contribution of individual subscale scores could be determined. Each test has four subscale scores that are summed to yield the total score. The AIMS subscales evaluate motor abilities by postural positions: prone, supine, sit and stand. The MAI subscale scores evaluate muscle tone, primitive reflexes, automatic reactions, and voluntary movement. The PDGMS subscales evaluate the integration of reflexes, the emergence of balance reactions, nonlocomotor motor abilities, and locomotor abilities.

Ten discriminant function analyses were performed: three evaluating the use of subscale scores of each measure obtained at the 4 month assessments as predictor variables, three evaluating the use of subscale scores of each measure obtained at 8 months of age, and three evaluating the classification

abilities when the subscale scores of each measure obtained from the 4 and 8 month assessments were combined. All of these analyses were performed with the predictor variables in each analysis entered simultaneously. The tenth analysis, using a stepwise method, entered twelve perinatal variables and all subscale scores of all three measures at both assessment times into the analysis in order to identify the combination of predictor variables that yielded the most accurate classification of infants at 18 months adjusted age. In all analyses, the outcome grouping was neurological outcome at 18 months (normal, suspicious, abnormal).

For each analysis, classification of cases was examined using two methods: resubstitution and jackknife. With resubstitution, all cases are used to generate the discriminant functions, and then each case is classified using the resultant discriminant scores. This method usually results in the highest classification rates, but overestimates the classification potential of the discriminant functions because the same cases used to calculate the functions are then classified (Betz, 1987). A more stringent method to test the functions' abilities to classify cases is the U or jackknife method (Norusis, 1992). With this method, the classification functions are computed from all the data except the case being classified. Each case is sequentially removed from the data and then classified using the resultant discriminant functions. This method is a special application of the hold-out method which computes the functions on a subset of the sample and then the classification rate is determined from the classification of the remaining cases. The hold-out method requires a large sample size and was not possible with this sample due to small number of cases in the suspicious and abnormal groups of infants.

Cases are assigned to the abnormal, suspicious or normal category based on the posterior probability assigned to each case. Posterior probabilities are computed using Baye's rule which takes into consideration the prior probability and conditional probability for each case. Prior probability is calculated from the number of cases in each of the classification categories.

3.5.3 Correlation between BSID II and the three infant motor measures used

The magnitude of the relationships between raw scores obtained on the MAI, AIMS, and PDGMS at 4 and 8 months, and raw scores on the Motor Scale of the BSID II at 18 months adjusted age were evaluated by calculating Pearson's product moment correlation coefficients. The BSID II was selected as the outcome measure since it is a widely used scale of infant development that has been re-normed recently.

3.6.0 Summary of methods

(i) A prospective longitudinal design was used.

(ii) The target population was at-risk infants cared for in neonatal intensive care units.

(iii) Inclusion criteria were: 1) infants weighing less than or equal to1500 grams at birth, 2) preterm infants weighing greater than or equal to 1500 grams with a history of IVH (Grade III or IV) or PVL, and 3) full-term infants with HIE Stage II or III.

(iv) Infants were assessed at 4 and 8 months adjusted ages on the AIMS, MAI, and PDGMS. A developmental pediatrician assessed each infant at 18 months adjusted age and classified his/her motor development as normal, suspicious, or abnormal.

(v) Data analyses included: 1) calculations of sensitivity, specificity, positive

predictive value and negative predictive value for a series of cut-off scores on the AIMS, and the recommended cut-off scores on the MAI and PDGMS, 2) a series of discriminant function analyses using different predictor variables, and 3) evaluation of the relationships between 4 and 8 month scores on the three measures and 18 month scores on the BSID II.

Chapter 4

RESULTS

4.0.0 Introduction

Results of the analyses are presented in this chapter. Sample descriptives and neurological outcomes of the infants are presented in the first section, followed by the results of computation of sensitivity, specificity, positive predictive values and negative predictive values. The results of the discriminant functions analyses are then presented, including an examination of individual scores of infants in the suspicious classification. Finally, the correlation coefficients computed between the scores obtained on the AIMS, MAI, and PDGMS at both 4 and 8 months and the raw scores obtained by the infants on the Motor Scale of the BSID II at 18 months adjusted age are examined.

4.1.0 Sample descriptives

One hundred and fifty-three infants were recruited into the study between January 1992 and January 1994, 59 infants less than the targeted sample size of 212. The main reason for the lower recruitment than proposed was an increased number of studies carried out in the two neonatal intensive care units, affecting parents' decision to enrol their infants in more than one study. Also, many of the infants from the University of Alberta Hospitals lived outside of Edmonton, and could not commit to returning to Edmonton for the assessments.

Of the 153 infants, ten families dropped out of the study, seven families moved and were unable to return to Edmonton, and two infants died before completing the study. One of the infants died unexpectedly before discharge from the NICU, and the other infant died of Sudden Infant Death Syndrome shortly after her 4 month assessment. One hundred thirty-four infants

completed the study, and were assessed by the developmental pediatrician at 18 months adjusted age. Nine of these infants had incomplete data, and were excluded from the analyses: seven infants were too old at their assessment to obtain accurate risk scores on the MAI, one infant was too ill for a 4 month assessment, and one infant had his leg in a cast at the 8 month assessment period. Complete data obtained on 125 infants were used for the final analyses.

The main effects of the small sample size are to increase the confidence intervals of the sensitivity values obtained, and decrease the stability of the classification abilities of the discriminant function analyses for the abnormal and suspicious groups. However, even if double the number of abnormal and suspicious infants were recruited, both problems would remain because of the small numbers. The only solution is to recruit equal numbers of normal, suspicious and abnormal infants (Hulley and Cummings, 1988). This option is not clinically feasible because of the low prevalence of motor dysfunction, and the time required to identify 100 abnormal/suspicious infants. It is also not desirable because increasing the prevalence of abnormal and suspicious infants to 50% of the sample would distort the positive and negative predictive values obtained. The stability of the discriminant function analyses was analysed stringently by using the jackknife method of classification, as described in chapter 3.

The sample consisted of 119 preterm infants ($\leq$36 weeks gestation) and 6 full-term infants ($\geq$37 weeks gestation). Sixty-five infants were male, 60 female. The mean birthweights and gestational ages for the preterm and the full-term infants are shown in Table 4.1. The generalizability of this sample to

Table 4.1

Birthweight and Gestational Age of Preterm and Full-term Infants

	Preterm n=119	**Full-term** n=6
Birthweight (grams)		
mean	1108.18	2825.83
standard deviation	313.40	524.81
range	380 - 2445	2080 - 3250
Gestational age (weeks)		
mean	28.45	39.50
standard deviation	2.67	1.38
range	22 - 36	38 - 41

infants seen at neonatal follow-up clinics can be evaluated by comparing the infants born in 1992 in this sample to the infants born in 1992 that are described in the 1994 annual report of the Glenrose Neonatal Follow-up Clinic. One hundred seventy-three infants born in 1992 and receiving neonatal intensive care were referred to follow-up using the criteria of the standard follow-up audit groups. Sixty infants in this study were born in 1992, representing 34.68% of the infants referred to follow-up in this time period. The proportion of infants less than 1250 grams are similar, 56.07% for the follow-up clinic and 61.67% for the study sample. The percentages of infants over 1250 grams are also similar, 29.48% for the follow-up clinic and 35.00% for the study sample. The follow-up clinic assessed a greater porportion of term infants with HIE (14.5% vs 3.33%).

4.1.1 Perinatal variables

As a group the median Apgar score at 1 minute was 5.0 with a range of 0 to 9. Values obtained for the Apgar scores at 5 minutes were: median 7.00, and range of 1 to 9. The average number of days in hospital for the sample was 70.63 with a standard deviation of 42.06 and a range of 6 days to 343 days. The frequencies of the remaining 7 perinatal variables are reported for the group in Table 4.2. The values obtained by each infant on the perinatal variables are provided in Appendix C, organized by outcome classification.

4.1.2 Test descriptives

The average ages of the infants at the 4 and 8 month assessments were 120 (SD ±3) days and 241 (SD ±3) days respectively (adjusted ages for preterm infants). Four and 8 month mean raw scores and standard deviations for each of the AIMS, MAI, and PDGMS for the entire sample, and for the three

Table 4.2

Descriptive Statistics of Perinatal Variables
(n=125)

Perinatal Variable		
		Median
Apgar score at 1 min.		5.00
Apgar score at 5 min.		7.00
		Mean (SD)
Length of stay (days)		70.63 (42.06)
		Frequencies
Days on Oxygen	none	25
	1-6 days	36
	7-14 days	6
	15-29 days	4
	>29 days	54
Seizures	Absent	107
	Present	18
PVL*	Absent	116
	Present	9
BPD*	Absent	85
	Present	40
IVH*	Absent	85
	Grade 1	14
	Grade 2	15
	Grade 3	6
	Grade 4	5
HIE*	Absent	119
	Stage 1	1
	Stage 2	5
	Stage 3	0
Size*	Appropriate	110
	Small	15

* PVL = Periventricular Leukomalacia
BPD = Bronchopulmonary Dysplasia
IVH = Intraventricular Hemorrhage
HIE = Hypoxic Ischemic Encephalopathy
Size = Size for gestational age

outcome classifications (normal, suspicious, abnormal) are presented in Tables 4.3 A, B and C. Raw test scores are provided for each infant in Appendix C, organized by outcome classification.

4.2.0 Neurological outcome at 18 months

At 18 months,100 infants (80.0%) were classified as normal in their motor development, 9 infants (7.2%) were classified as suspicious, and 16 infants (12.8%) were classified as abnormal in their motor development. Table 4.4 shows the distribution of full-term and preterm infants in each category. The diagnosis of each infant in the suspicious and abnormal categories is provided in Appendix D.

The prevalence rate of the suspicious group is slightly lower than the 15 to 25% usually cited in the literature (Bennett, 1988). 'Suspicious' infants typically include children identified with communication disorders and fine motor dysfunction. The classification of 'suspicious' in this study was limited to mild neuromotor abnormalities affecting only gross motor skills, and is similar to a recent study by Campbell et al. (1993) which also defined the suspicious group only by motor development, and reported a prevalence rate of 8.4%. Of the 9 infants in the suspicious classification, four had subtle signs of increased muscle tone, three were not yet walking, one had decreased deep tendon reflexes and was not yet walking, and one infant was classified as a 'toe walker'.

The prevalence rate of 12.8% for infants identified as abnormal in their motor development is comparable to rates cited in other studies (Campbell et al., 1993; Coolman et al., 1985; Ornstein et al., 1991). One infant had a diagnosis of severe developmental delay and hypotonia; the remaining 15

Table 4.3A

Raw Scores at 4 and 8 Months Adjusted Ages

	AIMS Total Score Mean (±SD)	MAI Total Risk Score Mean (±SD)	PDGMS Score Mean (±SD)
4 Months	12.6 (±4.1)	5.3 (±7.0)	46.9 (±10.9)
8 Months	30.5 (±10.7)	10.1 (±12.4)	85.8 (±25.3)

Table 4.3B

Raw Scores at 4 Months by Outcome Classification

	AIMS Total Score Mean (±SD)	MAI Total Risk Score Mean (±SD)	PDGMS Score Mean (±SD)
Normal	13.56 (±3.35)	3.22 (±3.67)	49.72 (±6.62)
Suspicious	11.22 (±5.29)	6.22 (±7.31)	44.33 (±15.51)
Abnormal	7.38 (±3.95)	18.00 (±9.44)	34.25 (±14.66)

Table 4.3C

Raw Scores at 8 Months by Outcome Classification

	AIMS Total Score Mean (±SD)	MAI Total Risk Score Mean (±SD)	PDGMS Score Mean (±SD)
Normal	34.06 (±7.65)	5.36 (±5.16)	94.87 (±15.56)
Suspicious	22.89 (±7.47)	17.11 (±13.55)	74.44 (±17.99)
Abnormal	12.13 (±7.08)	36.00 (±10.51)	47.69 (±21.08)

Table 4.4

Neurological Outcome Classification of Preterm and Full-term Infants

	Normal	Suspicious	Abnormal	Total
Preterm	97	9	13	119
Full-term	3	0	3	6
Total	100 (80.0%)	9 (7.2%)	16 (12.8%)	125

infants were diagnosed as having cerebral palsy. The types of cerebral palsy included spastic quadriplegia (n=4), athetoid (n=3), spastic triplegia (n=2) and spastic diplegia (n=6). Three of the 15 infants with cerebral palsy were full-term infants, with two classified as having athetoid cerebral palsy and one infant having spastic quadriplegia.

4.2.1 Group differences on perinatal variables

The means or frequencies of each perinatal variable according to three outcome classifications are presented in Table 4.5.

Group differences were evaluated for each perinatal variable using appropriate parametric or non-parametric statistics. Differences on each of the 12 variables, including birthweight and gestational age are presented in Table 4.6. There were no differences between infants in the three outcome classifications in terms of birthweight, gestational age or appropriateness of size. Infants in the normal and suspicious classifications differed only on the presence of periventricular leukomalacia and the presence of seizures, with an increased frequency of both in the suspicious group. Infants in the suspicious and abnormal groups differed on the presence of hypoxic ischemic encephalopathy and Apgar scores at 5 minutes. The most differences occurred between the infants in the normal and abnormal groups, with the poorer ratings obtained by infants in the abnormal group.

4.3.0 Sensitivity, specificity, positive and negative predictive values

Sensitivity, specificity, and positive and negative predictive values were calculated for each of the three motor measures (AIMS, MAI, PDGMS) at 4 and 8 months. Figure 4.1 shows the calculation of the four predictive values. All values are calculated from a two by two table. In order to accommodate the

Table 4.5

Perinatal Variables: Frequencies by Outcome Classification

		Outcome Classification		
Perinatal Variable		**Normal**	**Suspicious**	**Abnormal**
		Mean (SD)	**Mean (SD)**	**Mean (SD)**
Length of stay (dy)		64.90 (29.69)	85.33 (41.82)	98.19 (81.95)
		Median	**Median**	**Median**
Apgar score at 1 min.		5.00	4.00	3.00
Apgar score at 5 min.		8.00	8.00	6.00
		Frequencies	**Frequencies**	**Frequencies**
Days on Ventilation	none	24	0	0
	1-6 dy	32	2	2
	7-14 dy	5	0	1
	15-29 dy	4	0	0
	>29 dy	35	6	13
Seizures	Absent	93	6	8
	Present	7	3	8
PVL*	Absent	98	7	11
	Present	2	2	5
BPD*	Absent	73	5	7
	Present	27	4	9
IVH*	Absent	74	6	5
	Grade 1	12	0	2
	Grade 2	11	1	3
	Grade 3	3	1	2
	Grade 4	0	1	4
HIE*	Absent	97	9	13
	Stage 1	1	0	0
	Stage 2	2	0	3
	Stage 3	0	0	0
Size*	Appropriate	87	9	14
	Small	13	0	2

* PVL = Periventricular Leukomalacia
BPD = Bronchopulmonary Dysplasia
IVH = Intraventricular Hemorrhage
HIE = Hypoxic Ischemic Encephalopathy
Size = Size for gestational age

Table 4.6

Perinatal Variables: Pair-wise Group Differences

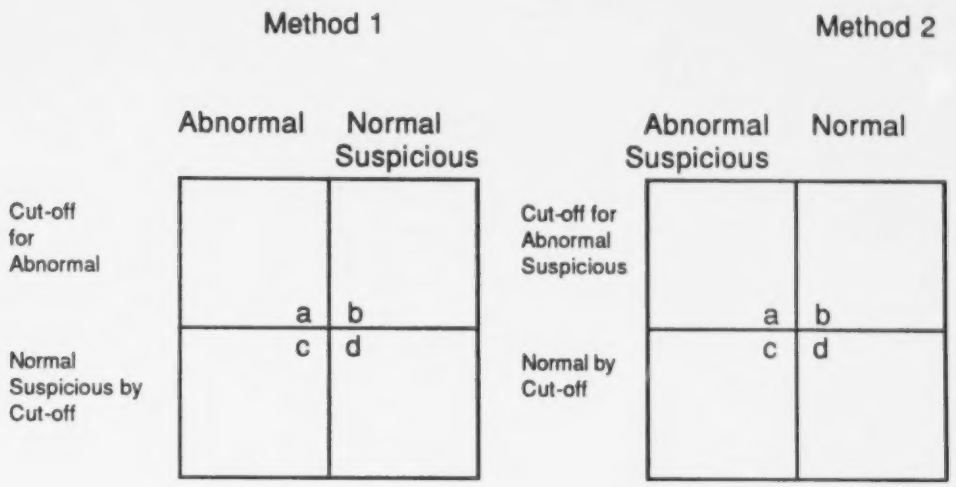
	Normal	Suspicious	No differences
Normal			BW GA Size
Suspicious	PVL Seizures		
Abnormal	Seizures PVL HIE Apgar1 Apgar5 Days in Days on O2 IVH BPD	HIE Apgar5	

Explanation of Terms:

BW	Birthweight in grams
GA	Gestational age in weeks
Apgar1	Apgar score at one minute
Apgar5	Apgar score at five minutes
Days in	Days in hospital before discharge
Days on O_2	Days on oxygen
Seizures	Presence or absence of seizures
IVH	Intraventricular Hemorrhage (graded 0 to 4)
PVL	Presence or absence of periventricular leukomalacia
HIE	Hypoxic Ischemic Encephalopathy (grade 0 to 3)
BPD	Presence or absence of bronchopulmonary dysplasia
Size	Appropriate for gestational age or small for gestational age

Figure 4.1

Classifications of Suspicious Infants in Calculation of Predictive Values



Sensitivity = a/(a + c)

Specificity = d/(d + b)

Positive Predictive Value = a/(a+b)

Negative Predictive Value = d/(d + c)

suspicious group, which represent a third classification category, two methods were used to calculate the values. First, the infants in the suspicious category were included with the infants in the normal category; second, the values were calculated combining the infants in the suspicious category with the infants in the abnormal classification.

On the AIMS, values for sensitivity, specificity, and positive and negative predictive values were calculated for each percentile rank from 0 to 25 (Appendix E). On the MAI, values were calculated using cut-offs of greater than 4 risk points and greater than 9 risk points. On the PDGMS, the cut-offs chosen were the 2nd percentile, the 6th percentile, and the 16th percentile rank. These values correspond to z scores of -2, -1.5 and -1 respectively, assuming a normal distribution.

4.3.1 Abnormal versus normal/suspicious grouping

Table 4.7 provides the sensitivity, specificity, and positive predictive and negative predictive values calculated for the three assessment measures when the infants classified as suspicious were grouped with the normal infants.

At 4 months, a cut-off score of greater than 9 on the MAI produced the most accurate predictive values (sensitivity 87.5%, specificity 91.7%, positive predictive value 60.9%, negative predictive value 98.0%). On the AIMS, the best cut-off point was the 10th percentile, yielding a sensitivity of 87.5%, specificity 78.0%, positive predictive value 36.8%, and negative predictive value of 97.7%. The PDGMS performed poorly; cut-offs at the 2nd percentile and the 6th percentile produced poor sensitivity values (43.8% and 56.2% respectively). If the 16th percentile was used as a cut-off the sensitivity improved to 81.2% but the specificity value decreased to 70.6%, resulting in many of the infants in the

Table 4.7

Sensitivity, Specificity, Positive and Negative Predictive Values:
Preterm and Full-term Infants (n=125)

Abnormal versus Normal/Suspicious Classification

Age	Test	Cut-off	Sensitivity	Specificity	+PV	-PV
4 mo.	AIMS%	2	50.0%	94.5%	57.1%	92.8%
		5	62.5%	88.1%	43.5%	94.1%
		6	62.5%	88.1%	43.5%	94.1%
		10	**87.5%**	**78.0%**	**36.8%**	**97.7%**
		16	87.5%	73.4%	32.6%	97.6%
	MAI-TRS	>4	87.5%	69.7%	29.8%	97.4%
		>9	**87.5%**	**91.7%**	**60.9%**	**98.0%**
	PDGMS%	2	43.8%	93.6%	50.0%	91.9%
		6	56.2%	90.8%	47.4%	93.4%
		16	81.2%	70.6%	28.9%	96.2%
8 mo.	AIMS%	2	81.2%	92.7%	61.9%	97.1%
		5	**100.0%**	**90.8%**	**61.5%**	**100.0%**
		6	100.0%	90.8%	61.5%	100.0%
		7	100.0%	89.0%	44.0%	100.0%
		16	100.0%	78.9%	41.0%	100.0%
	MAI-TRS	>4	100.0%	54.1%	24.2%	100.0%
		>9	100.0%	75.2%	37.2%	100.0%
	PDGMS%	2	93.8%	56.0%	23.8%	98.4%
		6	93.8%	49.5%	21.4%	98.2%
		16	100.0%	42.2%	20.3%	100.0%

normal/suspicious category identified as abnormal.

At 8 months, an AIMS cut-off score at the 5th percentile rank produced the most accurate predictive values (sensitivity 100.0%, specificity 90.8%, positive predictive value 61.5%, negative predictive value 100.0%). Indeed, all of the cut-off values from 0 to the 16th percentile on the AIMS produced excellent sensitivity and specificity values, all better than those obtained for the MAI or PDGMS at 8 months. The specificity values on the MAI and the PDGMS were low, resulting in an over-identification of normal/suspicious infants as abnormal in their motor development.

The sensitivity values obtained for all three tests at both ages were heightened because only infants with abnormal motor development were included in the grouping. Typically, because of the increased severity of the signs, it is easier to accurately identify these infants compared to the identification of infants categorized as having suspicious motor development.

4.3.2 Abnormal/suspicious versus normal grouping

Table 4.8 provides the sensitivity, specificity, positive and negative predictive values calculated for the three assessment measures when the infants classified as suspicious were grouped with the abnormal infants.

The sensitivity values dropped for all three assessment measures at both 4 and 8 months when the suspicious infants were included with the abnormal infants. Cut-off points on the AIMS produced excellent combinations of sensitivity and specificity at both ages. At 4 months, an AIMS cut-off score of the 10th percentile produced the following predictive values: sensitivity 72.0%, specificity 80.0%, positive predictive value 47.4%, and negative predictive value 92.0%. On the MAI a cut-off value of greater than 4 resulted in: sensitivity

Table 4.8

Sensitivity, Specificity, Positive and Negative Predictive Values:
Preterm and Full-term Infants (n=125)

Abnormal/Suspicious vs Normal Classification

Age	Test	Cut-off	Sensitivity	Specificity	+PV	-PV
4 mo.	AIMS%	2	40.0%	96.0%	71.4%	86.5%
		5	52.0%	90.0%	56.5%	88.2%
		6	52.0%	90.0%	56.5%	88.2%
		10	**72.0%**	**80.0%**	**47.4%**	**92.0%**
		16	72.0%	75.0%	41.9%	91.5%
	MAI-TRS	>4	76.0%	72.0%	40.4%	92.3%
		>9	64.0%	93.0%	69.6%	91.2%
	PDGMS%	2	32.0%	94.0%	57.1%	84.7%
		6	44.0%	92.0%	57.9%	86.8%
		16	68.0%	72.0%	37.8%	90.0%
8 mo.	AIMS%	2	64.0%	95.0%	76.2%	91.3%
		5	**80.0%**	**94.0%**	**76.9%**	**94.9%**
		6	80.0%	94.0%	76.9%	94.9%
		7	84.0%	93.0%	75.0%	95.9%
		10	88.0%	86.0%	61.1%	96.6%
		16	88.0%	83.0%	56.4%	96.5%
	MAI-TRS	>4	92.0%	57.0%	34.8%	96.6%
		>9	88.0%	79.0%	51.2%	96.3%
	PDGMS%	2	88.0%	59.0%	34.9%	95.2%
		6	88.0%	52.0%	31.4%	94.5%
		16	96.0%	45.0%	30.4%	97.8%

76.0%, specificity 72.0%, positive predictive value 40.4%, and negative predictive value 92.3%. A cut-off value greater than 9 yielded a relatively low sensitivity of 64.0% but a high specificity of 93.0%. On the PDGMS, the sensitivity values at 4 months were very low with cut-offs of either the 2nd or the 6th percentile; the 16th percentile increased the sensitivity to a modest 68.0% but lowered the specificity to 72.0%.

At 8 months the optimal cut-off score on the AIMS was the 7th percentile (sensitivity 84.0%, specificity 93.0%, positive predictive value 75.0%negative predictive value 95.9%). Designating either the 5th or 6th percentile rank as the cut-off point also produced excellent values of sensitivity (80.0%) and specificity (94.0%). On the MAI, the cut-off score of greater than 9 resulted in a sensitivity of 88.0% and a specificity of 79.0%. On the PDGMS, all three recommended cut-off points resulted in poor specificity and positive predictive values.

4.3.3 Predictive values using only preterm infants

Tables 4.9 and 4.10 show the predictive values obtained when only the data from the 116 preterm infants are used. The same pattern of values remains for all three measures and the best cut-offs for the full-term and preterm infants combined remain appropriate for the preterm group.

4.4.0 Discriminant function analyses

Ten discriminant function analyses were performed as described in chapter 3. For all analyses the grouping or criterion classification was neurological outcome at 18 months (normal, suspicious, abnormal). Three discriminant function analyses were performed for each of the three measures (AIMS, MAI, PDGMS). First, the subscale scores at 4 months for each measure were used as predictor variables, second, the subscale scores at 8 months for

Table 4.9

Sensitivity, Specificity, Positive and Negative Predictive Values:
Preterm Infants only (n=119)

Abnormal versus Normal/Suspicious Classification

Age	Test	Cut-off	Sensitivity	Specificity	+PV	-PV
4 mo.	AIMS%	2	38.5%	94.3%	45.5%	92.6%
		5	53.8%	87.7%	35.0%	93.9%
		6	53.8%	87.7%	35.0%	93.9%
		10	84.6%	77.4%	31.4%	97.6%
		16	81.2%	69.8%	28.9%	96.1%
	MAI-TRS	>4	84.6%	68.9%	25.0%	97.3%
		>9	**84.6%**	**91.5%**	**55.0%**	**98.0%**
	PDGMS%	2	43.8%	93.4%	50.0%	91.7%
		6	56.2%	90.6%	47.7%	93.2%
		16	81.2%	69.8%	28.9%	96.1%
8 mo.	AIMS%	2	76.9%	92.5%	55.6%	97.0%
		5	**100.0%**	**90.6%**	**56.5%**	**100.0%**
		6	100.0%	90.6%	56.5%	100.0%
		7	100.0%	89.6%	54.2%	100.0%
		10	100.0%	82.1%	40.6%	100.0%
		16	100.0%	80.2%	38.2%	100.0%
	MAI-TRS	>4	100.0%	54.7%	21.3%	100.0%
		>9	100.0%	76.4%	34.2%	100.0%
	PDGMS%	2	93.8%	54.7%	23.8%	98.3%
		6	93.8%	48.1%	21.4%	98.1%
		16	100.0%	40.6%	20.3%	100.0%

Table 4.10

Sensitivity, Specificity, Positive and Negative Predictive Values:
Preterm Infants Only (n=119)

Abnormal/Suspicious vs Normal Classification

Age	Test	Cut-off	Sensitivity	Specificity	+PV	-PV
4 mo.	AIMS%	2	31.8%	95.9%	63.6%	86.1%
		6	45.5%	89.7%	50.0%	87.9%
		10	**68.2%**	**79.4%**	**42.9%**	**91.7%**
		16	68.2%	74.2%	37.5%	91.1%
	MAI-TRS	>4	72.7%	71.1%	36.4%	92.0%
		>9	59.1%	92.8%	65.0%	90.9%
	PDGMS%	2	22.7%	93.8%	45.5%	84.3%
		6	36.4%	91.8%	50.0%	86.4%
		16	63.6%	71.1%	33.3%	89.6%
8 mo.	AIMS%	2	59.1%	94.8%	72.2%	91.1%
		5	**77.3%**	**93.8%**	**73.9%**	**94.8%**
		7	**81.8%**	**93.8%**	**75.0%**	**95.8%**
		10	86.4%	86.6%	59.4%	96.6%
		16	86.4%	84.5%	55.9%	96.5%
	MAI-TRS	>4	90.9%	57.7%	32.8%	96.6%
		>9	86.4%	80.4%	50.0%	96.3%
	PDGMS%	2	86.4%	57.7%	31.7%	94.9%
		6	86.4%	50.5%	28.4%	94.2%
		16	95.5%	43.3%	27.6%	97.7%

each measure were used as predictor variables, and finally the susbscale scores obtained at both assessment ages for each measure were used collectively as predictor variables. All nine discriminant function analyses were done by direct method, entering all predictor variables simultaneously.

The tenth discriminant function analysis, using a step-wise method, evaluated the combined contribution of all subscale scores obtained on all three measures and the 12 perinatal variables.

For all analyses, classification of individual infants, using both the resubstitution and the jackknife method, was examined. Prior probabilities were set by the number of infants in each outcome classification.

4.4.1 Four month subscale scores

Table 4.11 outlines the results of three discriminant function analyses using the 4 month subscale scores of each of the three motor measures independently as predictor variables. The results of the analysis using the AIMS subscale scores as predictor variables are discussed in detail to explain the results presented in the tables.

Two canonical discriminant functions are obtained with a three group classification. The functions provide the coefficients that maximally separate the means or centroids of the three classification groups. The functions are orthogonal to each other, and the first function usually provides the best discrimination among groups. The size of the standardized coefficients in each function indicates the predictor variables that contribute the most to prediction of group membership. For example, for the 4 month subscale scores on the AIMS, scores obtained on the SUPINE subscale have the highest weighting as a predictor variable (0.643) in the first function, followed by the scores of the

Table 4.11
Discriminant Function Analyses: 4 Month Subscale Scores

Test	Subscales	Sandardized Coefficients Function1	Function2	Eigenvalues		% of Variance	p-level
AIMS	PRONE4	0.191	0.389	Fcn1	0.433	93.0	0.00
	SUPINE4	0.643	0.413	Fcn2	0.033	7.0	0.28
	SIT4	0.005	0.127				
	STAND4	0.423	-0.974				
	Centroids	**Normal**	**Suspicious**	**Abnormal**			
	Fcn1	0.31	-0.61	-1.58			
	Fcn2	-0.03	0.62	-0.17			
MAI	MUSCLE4	-0.133	0.045	Fcn1	1.129	97.5	0.00
	PRIM4	-0.593	0.749	Fcn2	0.029	2.5	0.33
	AUTO4	-0.111	0.589				
	VOLIT4	-0.456	-1.242				
	Centroids	**Normal**	**Suspicious**	**Abnormal**			
	Fcn1	0.44	-0.08	-2.72			
	Fcn2	0.05	-0.60	0.06			
PDGMS	REFLEX4	0.407	-0.866	Fcn1	0.380	92.4	0.00
	BALANCE4	0.051	0.769	Fcn2	0.032	7.7	0.15
	NONLOC4	0.670	0.219				
	Centroids	**Normal**	**Suspicious**	**Abnormal**			
	Fcn1	0 .28	-0.43	-1.52			
	Fcn2	- 0.03	0.62	-0.14			

STAND subscale (0.423). The group means or centroids for the classification categories of normal (0.31), suspicious (-0.61), and abnormal (-1.58) derived in the first function indicate that an individual with a high discriminant score will be classified normal, and a progressively lower score will result in an abnormal classification. Thus, high subscale scores on both the SUPINE and STAND subscales increase the likelihood of an infant receiving a 'normal' classification.

The eigenvalue is a measure of the relative importance of each discriminant function derived. The sum of the eigenvalues is a measure of the total variance existing in the discriminating variables. When a single eigenvalue is expressed as a percentage of the total sum of eigenvalues, it provides a reference to the relative importance of the associated function (Nie, Hull, Jenkins, Steinbrenner and Bent, 1975). For example, function 1 accounts for 93.0% of the total variance accounted for by the two functions. Indeed, for the second discriminant function provided in this analysis, Wilks' lambda, a test for difference between the means of the groups, is not significant (p=0.275), indicating that the second function does not contribute significantly to group differences and contributes only minimally to the classification results.

Table 4.12 shows the classification results for both the resubstitution and jackknife methods using the discriminant scores obtained on each measure. Using the discriminant scores obtained from the 4 month AIMS subscale score data, the classification rate was only slightly lower for the jackknife method. This result suggests some stability in the classification ability of the discriminant functions although the sample size is rather small. As expected, with both classification methods, the infants receiving a suspicious outcome category were the most difficult to classify correctly, followed by classification of infants in

Table 4.12

Resubstitution and Jackknife Classifications: 4 Month Subscale Scores (N=125)

Resubstitution Classification Matrix

		Predicted Group Membership		
	Actual Group	Normal	Suspicious	Abnormal
AIMS n=100	Normal	98	1	1
n=9	Suspicious	7	1	1
n=16	Abnormal	8	1	7
	Per cent of cases classified correctly: 84.8%			
MAI n=100	Normal	99	0	1
n=9	Suspicious	8	0	1
n=16	Abnormal	5	0	11
	Per cent of cases classified correctly: 88.0%			
PDGMS				
n=100	Normal	100	0	0
n=9	Suspicious	8	0	1
n=16	Abnormal	10	0	6
	Per cent of cases classified correctly: 84.8%			

Jackknife Classification Matrix

	Predicted Group Membership		
Actual Group	Normal	Suspicious	Abnormal
Normal	98	1	1
Suspicious	7	0	2
Abnormal	9	2	5
Per cent of cases classified correctly: 82.4%			
Normal	99	0	1
Suspicious	8	0	1
Abnormal	6	0	10
Per cent of cases classified correctly: 87.2%			
Normal	99	0	1
Suspicious	8	0	1
Abnormal	11	1	4
Pe rcent of cases classified correctly: 82.4%			

the abnormal category at 18 months of age. Using the more stringent jackknife method, all the suspicious infants were misclassified by all three tests. The accuracy of the overall classification rates is high for all three tests, and is influenced by the large proportion of infants in the normal category. The large number of infants in the normal classification results in a high prior probability of any infant being classified in the normal category. The classification rates obtained on all three measures were very similar, and for all three tests, the results of the jackknife method of classification were similar to the resubstitution method.

4.4.2 Eight month subscale scores

Using the subscale scores obtained at 8 months (Table 4.13), the SUPINE subscale on the AIMS continued to contribute the highest weighting (0.884) to criterion group membership for function one, followed by the SIT subscale (0.388). Infants with higher scores will be classified as normal since this group has the highest centroid value (0.62). The second function, although able to distinguish between the means of the three groups ($p=0.05$), contributed only 3.36% to the between group variance. On the second function, the PRONE subscale on the AIMS had the largest standardized coefficient (1.29), indicating that a high score on the PRONE subscale increased the chances of an infant being placed in the final outcome classification of normal.

On the MAI subscales, risk scores obtained on the PRIMITIVE REFLEX subscale and the AUTOMATIC REACTIONS subscale received the highest weighting as reflected by the values of the standardized coefficients (-0.566 and -0.592 respectively). High negative scores increased the likelihood of an infant being placed in the abnormal category. The second function for the

Table 4.13
Discriminant Function Analyses: 8 Month Subscale Scores

Test	Subscales	Sandardized Coefficients Function1	Function2	Eigenvalues		% of Variance	p-level
AIMS	PRONE8	-0.151	1.294	Fcn1	1.98	96.6	0.00
	SUPINE8	0.884	-0.685	Fcn2	0.07	3.4	0.05
	SIT8	0.388	-0.096				
	STAND8	-0.019	-0.045				
	Centroids	**Normal**	**Suspicious**	**Abnormal**			
	Fcn1	0.62	-0.55	-3.54			
	Fcn2	0.06	-0.92	0.15			
MAI	MUSCLE8	-0.106	-0.091	Fcn1	2.83	98.2	0.00
	PRIM8	-0.566	-0.425	Fcn2	0.05	1.8	0.10
	AUTO8	-0.592	1.549				
	VOLIT8	0.032	-1.219				
	Centroids	**Normal**	**Suspicious**	**Abnormal**			
	Fcn1	0.77	-1.18	-4.14			
	Fcn2	-0.04	0.80	-0.18			
PDGMS	REFLEX8	-0.105	0.640	Fcn1	1.37	97.5	0.00
	BALANCE8	0.272	-0.854	Fcn2	0.03	2.5	0.25
	NONLOC8	1.221	-0.367				
	LOC8	-0.599	1.284				
	Centroids	**Normal**	**Suspicous**	**Abnormal**			
	Fcn1	0.52	-0.58	-2.93			
	Fcn2	0.04	-0.66	0.12			

discriminant analysis using MAI subscales contributed minimally to the classification procedure ($p = 0.105$).

On the PDGMS, a high score on items included in the NONLOCOMOTOR subscale made it more probable that an infant would be classified as normal, since this subscale had the largest coefficient for function 1 (1.22). As with the MAI, the second function made only a small contribution to the classification tables.

Classification results using the jackknife method (Table 4.14) reveal that AIMS scores at 8 months classified abnormal infants slightly more accurately than AIMS scores obtained at 4 months (89.6% compared to 82.4%), but the suspicious group continued to be misclassified, with only one infant correctly classified in the suspicious category at the 8 month assessment. Infants in the abnormal category were classified more correctly at 8 months (81.3%) compared to 4 months (31.3%). The MAI classification success rates were similar at 4 months (87.2%) and 8 months (88.8%), and the proportion of misclassified infants in the suspicious and abnormal categories were also similar at both ages.

The PDGMS scores produced similar classification rates at 4 months (82.4%) and 8 months (88.0%) as the AIMS scores. Like the AIMS scores, classification of suspicious infants continued to be poor at 8 months while the classification of infants in the abnormal category improved.

4.4.3 Four and eight month subscale scores combined

Table 4.15 outlines the results of the discriminant functions combining the scores obtained at both assessment ages. Reviewing the standardized coefficients for function 1, two subscale scores at 8 months on all three

Table 4.14

Resubstitution and Jackknife Classifications: 8 Month Subscale Scores

Resubstitution Classification Matrix

		Predicted Group Membership		
	Actual Group	Normal	Suspicious	Abnormal
AIMS n=100	Normal	98	1	1
n=9	Suspicious	7	1	1
n=16	Abnormal	2	1	13
	Per cent of cases classified correctly: 89.6%			
MAI n=100	Normal	99	1	0
n=9	Suspicious	5	1	3
n=16	Abnormal	2	2	12
	Per cent of cases classified correctly: 89.6%			
PDGMS				
n=100	Normal	99	0	1
n=9	Suspicious	7	0	2
n=16	Abnormal	5	0	11
	Per cent of cases classified correctly: 88.0%			

Jackknife Classification Matrix

	Predicted Group Membership		
Actual Group	Normal	Suspicious	Abnormal
Normal	98	1	1
Suspicious	7	1	1
Abnormal	2	1	13
Per cent of cases classified correctly: 89.6%			
Normal	99	1	0
Suspicious	5	1	3
Abnormal	2	3	11
Per cent of cases classified correctly: 88.8%			
Normal	99	0	1
Suspicious	7	0	2
Abnormal	5	0	11
Per cent of cases classified correctly: 88.0%			

Table 4.15
Discriminant Function Analyses: 4 and 8 Month Subscale Scores

Test	Subscales	Standardized Coefficients Function1	Function2	Eigenvalues		% of Variance	p-level
AIMS	PRONE4	-0.124	-0.434	Fcn1	2.130	94.9	0.00
	SUPINE4	-0.203	-0.009	Fcn2	0.144	5.1	0.08
	SIT4	-0.096	-0.205				
	STAND4	0.192	0.539				
	PRONE8	-0.059	1.245	Centroids	N	S	A
	SUPINE8	0.963	-0.573	Fcn1	0.65	-.75	-3.64
	SIT8	0.373	-0.152	Fcn2	0.07	-1.19	0.22
	STAND8	-0.003	-0.145				

		Function1	Function2	Eigenvalues		% of Variance	p-level
MAI	MUSCLE4	0.096	-0.150	Fcn1	2.86	96.0	0.00
	PRIM4	-0.050	-0.727	Fcn2	0.12	4.0	0.07
	AUTO4	0.023	-0.513				
	VOLIT4	-0.150	0.449				
	MUSCLE8	-0.119	-0.011	Centroids	N	S	A
	PRIM8	-0.552	-0.040	Fcn1	0.77	-1.17	-4.16
	AUTO8	-0.606	1.132	Fcn2	-0.07	1.20	-0.27
	VOLIT8	0.105	-0.709				

		Function1	Function2	Eigenvalues		% of Variance	p-level
PDGMS	REFLEX4	-0.047	0.741	Fcn1	1.45	94.1	0.00
	BALANCE4	0.156	-0.594	Fcn2	0.09	5.9	0.11
	NONLOC4	-0.396	-0.308				
	REFLEX8	-0.031	0.291				
	BALANCE8	0.191	-0.474	Centroids	N	S	A
	NONLOC8	1.465	-0.230	Fcn1	0.54	-0.59	-3.01
	LOC8	-0.652	1.152	Fcn2	0.06	-1.06	0.19

measures received the highest weighting, suggesting that the 8 month assessments contributed most to an infant's discriminant score when the assessments from the two ages were combined. The classification abilities (Table 4.16) of all three tests' discriminant functions were similar and did not improve substantially from the 8 month classification rates. Once again, the suspicious group of infants was the most difficult to classify correctly.

4.4.4 Step-wise discriminant function with all variables

In the final discriminant function, twelve perinatal variables (birthweight, gestational age, Apgar score at 1 minute, Apgar score at 5 minutes, days in hospital, days of assisted ventilation, presence or absence of seizures, presence or absence of periventricular leukomalacia, size (appropriate or small for gestational age), grade of intraventricular hemorrhage, bronchopulmonary dysplasia (presence or absence), and grade of hypoxic ischemic encephalopathy, and the subscale scores of all three measures at both ages were entered in a step-wise method. Only 124 cases were used in the analyses since one infant with abnormal motor development did not have a rating for Apgar score at one minute.

Three variables, the risk points on the AUTOMATIC REACTIONS subscale section of the MAI at 8 months, the risk points on the PRIMITIVE REFLEX section of the MAI at 8 months, and the presence or absence of periventricular leukomalacia, met the inclusion criteria (Table 4.17). The remaining variables did not significantly distinguish between the three outcome categories. The classification results (Table 4.18) are similar in accuracy to the classification matrices obtained using only the subscale scores of the individual measures at 8 months, suggesting redundancies of information among the

Table 4.16
Resubstitution and Jackknife Classifications: 4 and 8 Month Subscale Scores

Resubstitution Classification Matrix

		Predicted Group Membership		
	Actual Group	Normal	Suspicious	Abnormal
AIMS n=100	Normal	99	0	1
n=9	Suspicious	5	1	3
n=16	Abnormal	5	1	10
	Per cent of cases classified correctly: 88.0%			
MAI n=100	Normal	99	1	0
n=9	Suspicious	5	1	3
n=16	Abnormal	2	1	13
	Per cent of cases classified correctly: 90.4%			
PDGMS				
n=100	Normal	99	0	1
n=9	Suspicious	6	1	2
n=16	Abnormal	5	0	11
	Per cent of cases classified correctly: 88.8%			

Jackknife Classification Matrix

	Predicted Group Membership		
Actual Group	Normal	Suspicious	Abnormal
Normal	97	1	2
Suspicious	5	0	4
Abnormal	5	2	9
Per cent of cases classified correctly: 84.8%			
Normal	97	3	0
Suspicious	5	1	3
Abnormal	3	2	11
Per cent of cases classified correctly: 87.2%			
Normal	99	0	1
Suspicious	6	0	3
Abnormal	5	1	10
Per cent of cases classified correctly: 87.2%			

Table 4.17

Discriminant Function Analyses: Step-wise Method Using Perinatal Variables and All Subscale Scores

Summary Table of Variables Entered

Step No.	Variable entered	F Value to enter	U-statistic
1	AUTO8	118.310	0.338
2	PRIM8	16.089	0.267
3	PVL	4.864	0.247

Variable	Sandardized Coefficients Function1	Function2	Eigenvalues		% of Variance	p-level
PVL	0.301	0.582	Fcn1	2.92	98.9	0.00
PRIM8	0.483	-0.944	Fcn2	0.03	1.15	0.14
AUTO8	0.668	-0.6985				

Centroids	Normal	Suspicious	Abnormal
Fcn1	-0.77	1.39	4.30
Fcn2	-0.03	0.63	-0.16

Table 4.18

Resubstitution and Jackknife Classifications:
AUTO8, PRIM8 and PVL

Resubstitution Classification Matrix

		Predicted Group Membership		
	Actual Group	Normal	Suspicious	Abnormal
n=100	Normal	98	2	0
n=9	Suspicious	5	1	3
n=16	Abnormal	1	3	11

Per cent of cases classified correctly: 88.7%

Jackknife Classification Matrix

	Predicted Group Membership		
Actual Group	Normal	Suspicious	Abnormal
Normal	98	2	0
Suspicious	5	1	3
Abnormal	1	4	10

Per cent of cases classified correctly: 87.9%

variables.

4.4.5 Case studies of misclassified infants in the suspicious category

To further evaluate the individual classification of infants in the suspicious category using AIMS data, a final discriminant function analysis was done using only the AIMS scores of infants classified as abnormal or normal at 18 months adjusted age as predictor variables. This evaluation provides a discriminant function that maximally separates the normal group from the abnormal group. AIMS subscale scores from both assessment periods were used. The resultant discriminant function equation was then used to derive the discriminant score for each of the 9 infants classified as suspicious at 18 months adjusted age.

Cases are assigned to either the abnormal or normal category based on the posterior probability assigned to each case. Posterior probabilities are computed using Baye's rule which takes into consideration the prior probability and conditional probability for each case. Prior probability is calculated from the number of cases in each of the classification categories. In this situation, the prior probability of receiving a normal classification is 0.86 (100/116), and the prior probability of receiving an abnormal classification is 0.14 (16/116). Conditional probability is determined by assuming a multi-variate normal distribution of the discriminant function scores for each of the two groups and, dependent on the generalized distance of an individual's discriminant score from each group's centroid vector, the probability of obtaining a particular generalized distance value if the case is a member of the group, using the chi-square distribution with 2 degrees of freedom. Thus, an individual's group membership is determined by the prior probability of belonging to a group, the

individual's discriminant scores from the two group centroids, and dispersion of relative cases location around the centroids.

The standardized coefficients generated for the eight subscales indicate that the scores obtained on the SUPINE subscale and the SIT subscale at 8 months are most highly weighted in the discriminant equations (Table 4.19). The means for the normal (0.59) and abnormal (-3.72) groups suggest good discrimination between the groups.

Using the discriminant scores obtained for each case and the prior probabilities, one infant (case 2) was classified as abnormal and the remaining eight infants were classified as normal. The posterior probabilities were high except for two cases 19 and 31, indicating that the classification of most of the infants using the discriminant function equation was unambiguous. For cases 19 and 31, even though their discriminant scores were closer to the mean score for the abnormal group than the normal group, the high prior probability of receiving a normal classification influenced their placement into the normal category.

A final discriminant function was performed classifying the infants in the suspicious group according to the classification each received in the previous analysis. Thus, one infant was classified as abnormal and the remaining eight infants were classified as normal. The resultant discriminant function equation (Table 4.20) could be used in a neonatal follow-up clinic to classify new cases into a predicted outcome of normal or abnormal motor development, based on AIMS subscale scores obtained at 4 and 8 months of age.

4.6.0 Correlation of measures with 18 month scores on the BSID II

Pearson's product-moment coefficients were calculated to evaluate the

Table 4.19
Discriminant Function Analysis: 4 and 8 Month AIMS Subscale Scores
from Infants in Normal and Abnormal Categories (n=116)

Subscales	Standardized Coefficients	Eigenvalue	% of Variance	p-level
PRONE4	-0.071	2.249	100.0	0.00
SUPINE4	-0.134			
SIT4	-0.094			
STAND4	0.205			
PRONE8	-0.114	**Centroids**	**Normal**	**Abnormal**
SUPINE8	0.938		0.59	-3.72
SIT8	0.408			
STAND8	-0.051			

Classification of Suspicious Infants from Discriminant Function Equation

Case	Classification	Conditional Probability	Posterior Probability	Discriminant Score
2	Abnormal	0.207	0.883	-2.454
19	Normal	0.013	0.591	-1.901
26	Normal	0.868	1.000	0.761
31	Normal	0.013	0.605	-1.888
32	Normal	0.148	0.993	-0.853
40	Normal	0.670	0.999	0.168
74	Normal	0.393	0.999	-0.260
88	Normal	0.632	0.999	0.116
95	Normal	0.228	0.997	-0.610

Table 4.20

Discriminant Function Analysis: Infants in Suspicious Category Reclassified

AIMS subscales	**Standardized Coefficients**
PRONE4	-0.005
SUPINE4	-0.026
SIT4	-0.062
STAND4	0.091
PRONE8	-0.162
SUPINE8	0.891
SIT8	0.447
STAND8	-0.105

Centroids	**Normal**	**Anormal**
	0.55	-3.51

relationship between the raw scores obtained on the Motor Scale of the BSID II at 18 months and the raw scores obtained on the three assessment measures at 4 and 8 months (Table 4.21). At both assessment periods, the MAI had the highest correlation coefficients with the BSID II, and the coefficients obtained on the AIMS and the PDGMS were very similar. For all three assessment measures, their relationships with the BSID II increased in magnitude at 8 months compared to 4 months. All correlations were significant ($p<0.01$).

4.7.0 Summary of findings

The data were analysed primarily by two methods: calculation of sensitivity, specificity, negative predictive value and positive predictive value, and a series of discriminant function analyses. The following points summarize the findings from each method.

4.7.1 Sensitivity/specificity findings

(i) At 4 months, to identify only infants with abnormal motor development, a cut-off of greater than 9 on the MAI produced the best combination of sensitivity and specificity values.

(ii) At 4 months, to identify both infants with abnormal motor development and infants with suspicious motor development, a cut-off on the AIMS at the 10 percentile rank produced the best combination of sensitivity and specificity values.

(iii) At 8 months, a cut-off point of the 5th percentile rank on the AIMS produced excellent sensitivity and specificity values for the identification of both infants with abnormal motor development and infants with abnormal or suspicious motor development.

(iv) Specificity values on the MAI were poor at the 8 month assessment period.

Table 4.21

Correlations between BSID II Scores at 18 months and AIMS, MAI and PDGMS Raw Scores at 4 and 8 Months

4 Month Assessment

	AIMS	MAI	PDGMS
Bayley Raw Score	0.42	-0.6	0.4

8 Month Assessment

	AIMS	MAI	PDGMS
Bayley Raw Score	0.5	-0.65	0.5

(v) The PDGMS yielded poor combinations of sensitivity and specificity values at both assessment ages, and with both grouping strategies for the suspicious infants.

(vi) As expected, inclusion of infants in the suspicious category with infants in the abnormal category reduced markedly the sensitivity values of all three measures at both assessment ages.

(vii) The same cut-off points are identified when full-term infants are removed from the sample and preterm infants are considered separately.

4.7.2 Summary of findings from discriminant function analyses

(i) When discriminant scores are used to predict the classification of infants at 18 months adjusted age, all three tests have similar classification abilities.

(ii) The combination of 4 and 8 months scores did not improve the classification results obtained by using only 8 months subscale scores.

(iii) Inclusion of perinatal variables did not improve classification abilities.

(iv) Classification of infants in the normal category is very accurate.

(v) Classification of infants in the abnormal category improves at the 8 month assessment period.

(vi) Classification of infants in the suspicious category is difficult for all three tests at both assessment periods.

Chapter 5

DISCUSSION

5.1.0 Summary of the study

The AIMS is a recently developed observational measure of infant gross motor development that emphasizes the analysis of voluntary movement skills. Because the AIMS is being used in neonatal follow-up clinics, clinicians need information on its predictive validity in terms of its ability to identify at an early age infants who will eventually demonstrate either abnormal or suspicious motor development. Accurate identification of these infants is essential for the provision of early treatment to the appropriate group of infants. Also, the efficacy of early treatment cannot be evaluated if normally developing infants are mislabelled as abnormal, and thus receive treatment.

The study had two main objectives. The first objective was to identify the percentile ranks on the AIMS that most accurately predict the motor outcome of at-risk infants at 18 months of age, and to evaluate the predictive validity of the selected cut-offs. The second objective was to evaluate the assumption arising from the neuromaturational theory of motor development that eventual motor abilities of children can be accurately predicted from the assessment of their motor skills in infancy.

One hundred and twenty-five at-risk infants were recruited from two neonatal intensive care units in Edmonton. At 4 and 8 months adjusted ages they were assessed on three motor measures: the AIMS, the MAI and the PDGMS. At 18 months of age the infants were evaluated by a developmental pediatrician who classified each infant's motor abilities as normal, suspicious, or abnormal. By calculating the sensitivity, specificity, and positive and negative

predictive values for each percentile rank on the AIMS from 0 to 25, the percentile ranks were identified that most accurately identified the outcome classification of infants. To evaluate the theoretical assumption that early prediction is feasible, the predictive abilities of all three tests were examined, and the best combinations of sensitivity and specificity at the two assessment ages were determined. In addition, a series of discriminant function analyses were performed to examine the classification abilities of each motor measure at each age.

5.2.0 Findings of the study

The evaluation of a series of cut-off percentiles on the AIMS revealed different percentile ranks for cut-offs at the two assessment ages: the 10th percentile at 4 months, and the 5th percentile at 8 months. This result differs from traditional norm-referenced tests that advocate the use of the same cut-off for all ages. In addition, for each of the two ages, the same AIMS percentile rank can be used to accurately identify either infants with abnormal motor development, or infants with abnormal or suspicious motor development. This result also differs from traditional norm-referenced tests that use different cut-offs for the identification of infants with suspicious motor development and infants with abnormal motor development.

With regard to the assumption that early motor abilities can be used to predict eventual motor function, the results suggest that accurate prediction of infants with normal and abnormal motor development can be achieved as early as 4 months if the test assesses the components of motor development most dominant at that age. Stated differently, the motor constructs measured by the test must match the stage of motor development exhibited by the infant. As

expected, children with a suspicious motor outcome are the most difficult to identify in infancy.

5.3.0 Conclusions

5.3.1 Cut-offs on the Alberta Infant Motor Scale

The diametric differences between traditional recommendations for cut-offs on norm-referenced tests, and the results of this study regarding the use of cut-offs on the AIMS are summarized below.

	AIMS	Traditional Norm-Referenced Tests
Age of Infant at Assessment	Different cut-offs	Same cut-off
Identification of Abnormal vs. Abnormal/Suspicious Infants	Same cut-off	Different cut-offs

(i) Age of infant at assessment

With traditional norm-referenced tests, the same cut-offs are used regardless of the age of the infant at the time of assessment. For example, the authors of the PDGMS suggest that several school districts and states across the United States have adopted minus 1.0 standard deviation and minus 1.5 standard deviations as cut-off points to identify moderate and severe deficits respectively, regardless of the child's age (Folio and Fewell, 1983, p.125). On the AIMS, however, the 10th percentile as a cut-off at 4 months and the 5th percentile at 8 months yield the most accurate combination of sensitivity and specificity values.

The components of motor abilities assessed on the AIMS, and the degree of voluntary movement demonstrated by infants at the two ages are

most likely the factors responsible for the identification of different cut-offs at 4 and 8 months. At earlier stages of development, up to and including 4 months, items on the AIMS emphasize the assessment of age-appropriate postures. With the exception of assessing head control, little voluntary movement is expected in the early items of each subscale. However, as an infant matures, voluntary movements are emphasized in the descriptors for each item. Specifically, weight shift, rotation within the body axis, and the ability to dissociate one body part from another are the components of voluntary movement evaluated by items on the AIMS at older ages.

The higher cut-off for the identification of abnormal and suspicious infants at 4 months suggests that many infants with eventual movement dysfunction passed the early items on the AIMS that evaluate resting postures and emerging head control, and received a total raw score approaching the 10th percentile. Thus, both normal and abnormal infants received credit for some of the early items on the AIMS, and the higher cut-off was necessary to distinguish between the two groups of infants.

At 8 months, infants with eventual suspicious or abnormal motor development did not pass many of the items typically observed at this age, as shown by the identification of the 5th percentile as a cut-off. At this age the items on the AIMS evaluate more complex components of motor skills such as weight shift, rotation and dissociated movements. These voluntary movements represent the hallmark of normal motor development (Bly, 1980), and are precisely the components of movement that infants with motor dysfunction have difficulty performing. Thus, evaluation of these complex, voluntary components of motor development on the AIMS distinguished infants with normal motor

skills from infants with abnormal or suspicious motor skills at a lower percentile cut-off than the cut-off identified at 4 months.

In summary, the higher cut-off was identified at 4 months because many infants with abnormal or suspicious motor development were able to pass the early items on the AIMS that emphasize the attainment of specified postures. In contrast, a lower cut-off was identified at 8 months because the format of the items emphasizes controlled, voluntary movement, and the majority of the infants with abnormal motor development failed these items.

(ii) Identification of abnormal vs. abnormal/suspicious infants

At both 4 and 8 months, the cut-offs recommended on the AIMS to identify infants with abnormal motor development can also be used to screen for infants with suspicious motor development. Typically a cut-off equivalent to minus 2 standard deviations (2nd percentile) is recommended to identify infants with significantly delayed motor abilities, and a cut-off equivalent to minus 1 standard deviation (16th percentile) is recommended to identify infants with mild or suspicious motor delays (Bayley, 1993; Folio and Fewell, 1983). The use of these cut-offs is based on the assumption that infants with suspicious motor development have motor abilities that are superior to the skills of infants with abnormal motor skills, but inferior to the skills of normally developing infants. That is, their motor abilities 'fall between' the two extremes of abnormal and normal motor abilities, and by increasing the cut-off percentile, the balance between sensitivity and specificity will be maintained.

When the recommended cut-offs on the AIMS of the 10th percentile at 4 months and the 5th percentile at 8 months were used for the identification of suspicious as well as abnormal infants, the sensitivity values decreased

compared with the identification of only infants with abnormal motor development (Tables 5.1 and 5.2), but the high specificity rates were maintained. If a higher cut-off was used at either age, the sensitivity values increased slightly but the false positive identification of normally developing infants increased (specificity decreased). Thus, although the sensitivity values obtained with these cut-offs decreased with the inclusion of suspicious infants in the abnormal category, the high specificity values obtained support their use as cut-offs when the intent of screening is to identify infants with either abnormal or suspicious motor development.

Percentile ranks obtained from the raw scores of the suspicious infants ranged from the 0 to the 75th percentile at 4 months, and from the 0 to the 35th percentile at 8 months. These scores confirm that it is extremely difficult to identify all infants with suspicious motor development at either the 4 or 8 month assessment without obtaining a high false positive rate of identification of normally developing infants. These results suggest that the motor abilities of infants who eventually receive an outcome classification of suspicious do not 'fall between' abnormal and normal motor abilities, but rather that the early motor abilities of many of these infants resemble the motor abilities of normally developing infants. The discriminant function classification matrices also support this premise; the 'suspicious' infants were the most difficult to classify regardless of the predictor variables used, with the majority of the nine suspicious infants being classified as normal.

Evaluation of the selected cut-offs support the conclusion that the AIMS can be used as a predictive index with at-risk infants. As expected, the predictive abilities of the test are better when only infants with definite abnormal

Table 5.1

Prediction of Abnormal versus Normal/Suspicious Infants
AIMS and MAI

	4 months		8 months	
Abnormal	AIMS	87.5%	AIMS	100.0%
	MAI	87.5%	MAI	100.0%
Normal/Suspicious	AIMS	78.0%	AIMS	90.8%
	MAI	91.7%	MAI	75.2%

Table 5.2

Prediction of Abnormal/Suspicious versus Normal Infants

	4 months		8 months	
Abnormal/Suspicious	AIMS	72.0%	AIMS	80.0%
	MAI	64.0%	MAI	88.0%
Normal	AIMS	80.0%	AIMS	94.0%
	MAI	93.0%	MAI	79.0%

motor development are the target of screening. Inclusion of infants with suspicious motor development in the screening process decreases the sensitivity values obtained.

5.3.2 Prediction of eventual motor abilities from early motor abilities

This study evaluated the assumption that early motor abilities in infancy accurately predict later motor abilities in early childhood. Two possible explanations for the current reported poor record of early prediction of long-term outcome were suggested in chapter 1: 1) lack of appropriate assessment tools, and 2) incorrect assumptions underlying the neuromaturational theory of motor development. The influence of these two explanations were evaluated by comparing the predictive validity of the AIMS with the predictive abilities of two tests of motor function in current use. The hypothesis was that, if poor test development was the main factor for the inability to predict long-term outcome, then the AIMS should demonstrate better predictive abilities than the MAI or PDGMS, given its strong psychometric properties and the detailed analyses of components of motor milestones. However, if poor prediction was due to incorrect theoretical assumptions regarding the evolution of motor skills, the AIMS would not exhibit better predictive abilities than the present tests.

The results of this study suggest that early prediction of infants with normal or abnormal motor development is possible. However, the initial hypothesis was too simplistic. Accurate prediction may depend not only on the psychometric rigor of the measure used, but also on the match between the constructs of motor development assessed by the measure, and the developmental stage exhibited by an infant at different ages. The accuracy of prediction also appears to be influenced by the assessor's experience with

normally developing infants. Finally, infants with suspicious motor development at 18 months are the most difficult group to identify at an early age.

(i) Predictive abilities of the three measures

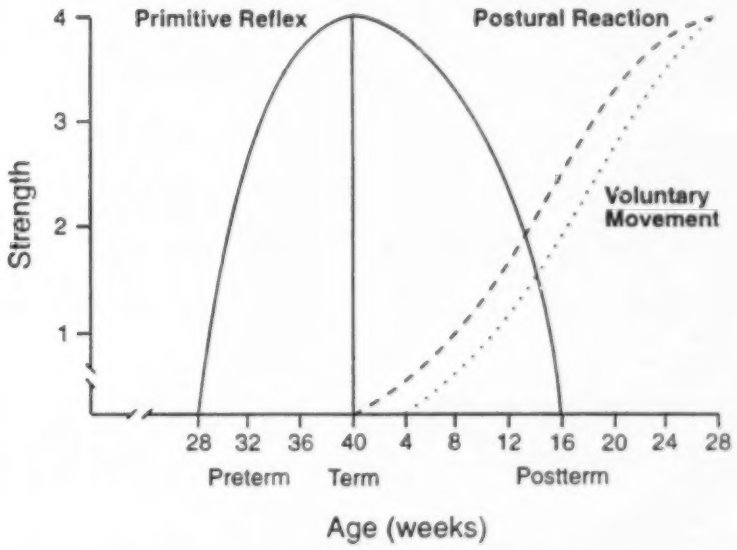
The predictive validity of the AIMS was best at 8 months compared to either the MAI or PDGMS. At 4 months the MAI demonstrated better specificity values than the AIMS. The PDGMS performed poorly at both ages.

When infants in the suspicious category were grouped with infants in the normal classification the AIMS and MAI identified the same proportion of infants with abnormal motor development at 4 months (87.5%) and 8 months (100.0%) (Table 5.1). When infants classified as suspicious were combined with the infants in the abnormal category, the sensitivity values at both ages decreased (Table 5.2) on both tests. Thus, the two tests demonstrate similar abilities to identify infants with abnormal or suspicious motor development. However, the specificity values obtained on the two tests differed at the two ages; at 4 months the MAI demonstrated higher specificity while at 8 months the AIMS had better specificity. Why do the two tests differ in the identification of normally developing infants at the two ages?

The ages of 4 and 8 months may represent two distinct stages of motor development, and different components of motor performance may discriminate best between normal and abnormal motor development at the two stages. Campbell (1984) proposed the normal relationship between primitive reflexes, postural reactions, and motor development illustrated in Figure 5.1. In this neuromaturational model, the influence of the primitive reflexes on motor development decreases in normally developing infants around 4 months, and is replaced by the increasing influence of voluntary movements and postural

Figure 5.1

Theoretical relationship of primitive reflexes, postural reactions and voluntary movement in normally developing infants



From Campbell SK, 1984, p 74

reactions. By 6 months of age, mature voluntary movement is dominant in the repertoire of normally developing infants.

Using Campbell's framework, at 4 months the MAI, by testing primitive reflexes in isolation, may use the motor construct that best distinguishes normal from abnormal motor development at this developmental stage. Primitive reflexes in normally developing infants will have been integrated, while their influence will still be observed in the motor abilities of abnormally developing infants. In the discriminant function derived using the MAI subscale scores at 4 months as the predictor variables, the primitive reflex subsection had the largest coefficient, thus influencing significantly an infant's group classification at 18 months. This supports the premise that the extent of integration of primitive reflexes at 4 months is a strong predictor of outcome classification at 18 months of age.

At 8 months, AIMS' items emphasize the integration of postural reactions and voluntary movement in the performance of motor milestones. This emphasis on voluntary movement may be responsible for the very accurate identification of normally developing infants using the AIMS at this age. Although the MAI also evaluates postural control and voluntary movement, the style of assessment, which requires extensive handling, may impede the observation of the infant's true spontaneous abilities. The observational format of the AIMS, with minimal handling and positioning, allows evaluation of an infant's voluntary movements in a holistic, natural manner, and may contribute to the more accurate identification of normally developing infants at this stage of development.

This explanation that the assessment of the unique stage of motor

development exhibited at different ages can improve prediction concurs with the neuromaturational theory of motor development. Both Gesell (1938) and McGraw (1945) proposed that an infant's level of neurological maturity was manifested in the patterns of motor behavior observed. They proposed that primitive reflexes were integrated as the cerebral cortex matured and inhibited the lower centres of the brain. Thus, a prolonged retention of primitive reflexes was indicative of CNS pathology. This premise is supported by the finding that the extent of integration of primitive reflexes at 4 months distinguishes between infants with abnormal and normal motor development at 18 months of age.

Specificity values obtained on the MAI at 8 months are lower than those obtained at 4 months. Using Campbell's model, this finding can be explained by the fact that voluntary movement, the dominant developmental stage at 8 months, is not sufficiently emphasized in the MAI assessment. A psychometric issue may also explain the reduced specificity at this age. At 8 months, because of the authors' designation of risk status to more responses, 61 potential risk points can be accrued compared to 48 at 4 months, even though the cut-off point is the same for both ages. Therefore, an infant has a greater possibility of receiving more than 9 risk points at the 8 month assessment. Also, the assignment of risk points to indicate deviancy at 8 months may be too stringent to allow for the wide variability in motor skills observed in infants at this age. For example, for two items in the volitional movement subscale, 'sits when placed', and 'prone progression', an 8 month old infant receives risk points if he or she is not yet creeping on hands and knees, or sitting well independently. Both of these expectations are restrictive guidelines for motor development at 8 months and, as a result, normally developing infants may accrue more than 9

risk points. Thus the lower specificity values obtained on the MAI at 8 months may be due to either lack of emphasis on the motor construct of voluntary movement, or weak psychometric properties because of an incorrect cut-off choice at 8 months. Further evaluation of cut-offs on the MAI is necessary to identify the influence of these two possible factors.

The MAI specificity values obtained in this study are considerably higher at both ages than previously reported specificity values. Swanson et al. (1992) reported specificity values of 78.2% (normal infants) and 72.2% (normal/suspicious infants) at 4 months, and 64.5% (normal infants) and 59% (normal/suspicious infants) at 8 months. In comparison, this study reports specificity values of 93.0% (normal infants) and 91.7% (normal/suspicious infants) at 4 months, and 79.0% (normal infants) and 75.2% (normal/suspicious) at 8 months. The higher specificity values obtained in this study may be a result of the clinical experience of the two assessors. Both physical therapy assessors have over twenty years experience in the assessment of preterm infants. In addition, both therapists participated in the collection of normative data on the AIMS and assessed hundreds of full-term, normally developing infants. Because of their exposure to many normally developing infants, these therapists may have allowed more variability for normal responses when scoring the MAI, thus resulting in the assignment of fewer risk points.

The recommended cut-offs for the PDGMS did not provide acceptable combinations of sensitivity and specificity values at either age and for any grouping of the suspicious infants (Table 5.3). At 4 months the sensitivity values were low and the specificity values high, while at 8 months the sensitivity values were high and the specificity values were unacceptable. The content of the

Table 5.3

Predictive Values: Peabody Developmental Gross Motor Scale

		4 months	8 months
Abnormal	2%	43.8%	93.8%
	6%	56.2%	93.8%
	16%	81.2%	100.0%
Normal/Suspicious	2%	93.6%	56.0%
	6%	90.8%	49.5%
	16%	70.6%	42.2%
Abnormal/Suspicious	2%	32.0%	88.0%
	6%	44.0%	88.0%
	16%	68.0%	96.0%
Normal	2%	94.0%	59.0%
	6%	92.0%	52.0%
	16%	72.0%	45.0%

items on the PDGMS provide the most likely explanation for these results. The 4 to 5 month items include many that can be accomplished by infants with impaired motor function (extending arms and legs, pedalling action, propping on extended arms). In contrast, the 8 to 9 month items involve complex skills (pivoting, creeping position, crawling) that many normally developing infants are not yet practising. In addition, two items, 'raising up' and 'scooting', are rarely observed, even in infants with normal gross motor abilities. This combination of difficult and eccentric items may contribute to the low levels of specificity achieved on the PDGMS at 8 months.

The classification rates obtained from the discriminant function analyses were similar for all three tests at both assessment ages. This finding is in contrast to the different sensitivity and specificity rates obtained for the three tests, especially the PDGMS. The discrepancy in the findings suggests that the cut-off points recommended for the MAI and the PDGMS may not be the optimal cut-offs for the identification of infants in the abnormal and normal classification categories. Evaluation of different cut-offs on both tests may improve their classification abilities.

(ii) Prediction of infants with suspicious motor skills

When infants in the suspicious category are included with infants in the abnormal category for early identification, the sensitivity values of both the AIMS and the MAI decrease (Table 5.2). This result emphasizes the difficulty in identifying all infants with suspicious motor development without decreasing specificity. At 4 months the AIMS was able to identify two more infants with suspicious motor development than the MAI, but the MAI identified correctly 13 more normally developing infants than the AIMS. Conversely, at 8 months,

although the sensitivity values of both tests improved, the MAI identified two more infants with suspicious motor development compared to the AIMS, while the AIMS identified correctly 15 additional normally developing infants compared to the MAI. The results of the series of discriminant function analyses emphasize the difficulty in correctly classifying infants in the suspicious category. At 4 months, using the subscale scores of any of the three measures as predictor variables, none of the suspicious infants was correctly classified. At 8 months, only 1 suspicious infant was correctly identified using the subscale scores of either the AIMS or MAI.

Suspicious infants represent a heterogeneous group with an array of diagnoses at 18 months of age. Three infants received a diagnosis of developmental delay, four had evidence of increased muscle tone, one was a 'toe-walker', and the last infant had mild gross motor delay. Four of the families were contacted by telephone when the infants were 24 months or older to determine the subsequent developmental outcome of the children. The infant with the lowest scores at 4 and 8 months in the suspicious group (case #2), is now four years old and her mother reported no problems in any area of development. In contrast, infant #21, who also had low scores on the AIMS and a high number of risk points on the MAI at both ages, was still not walking at 28 months and was scheduled for a pediatric assessment at a rehabilitation center. Of the other two infants, one is doing very well by mother's report, and the other has a severe language delay at the age of 3 years and is receiving speech therapy. Due to the wide array of underlying conditions represented in this group of infants, it does not seem possible, by the assessment of infant gross motor skills, to accurately distinguish children who will continue to have

problems in their development from those children who will eventually exhibit normal development. The AIMS and the MAI appear similar in their abilities to accurately detect infants with suspicious motor development.

Earlier research suggests that approximately one-half of these infants will progress to a normal classification by 24 months of age, one-quarter will remain suspicious in their development, and the remaining one-quarter will eventually be classified as abnormal in their development (Piper, Mazer, Silver and Ramsay, 1988). Clearly 18 months is too early to establish a definitive outcome for these infants.

5.4.0 Recommendations

Clinical recommendations are provided for the three main topics addressed in the conclusions: 1) cut-offs on the AIMS, 2) selection of an appropriate test, and 3) early prediction of eventual motor abilities. Research recommendations are then suggested.

5.4.1 Cut-offs on the AIMS

Screening for motor dysfunction in the first year of development should attempt to identify infants with either suspicious or abnormal motor development without mislabelling infants with normal motor abilities. At 4 months the 10th percentile is recommended as a cut-off on the AIMS to detect infants with either suspicious or abnormal motor development. At 8 months the 5th percentile is identified as the best cut-off for the identification of both groups of infants. The use of the same cut-off for the identification of either infants with abnormal or suspicious motor development simplifies the clinical interpretation of test scores. It is important that clinical decisions are not made on the basis of one standardized test assessment. The cut-offs recommended are to be used as

guidelines for the interpretation of AIMS scores. Final decisions regarding management of an individual infant must be made only after considering all assessment findings.

5.4.2 Selection of appropriate test

Either the AIMS or the MAI may be used to identify infants with suspicious or abnormal motor development. Even though the specificity values obtained using the MAI at 4 months are higher than those obtained using the AIMS, the simplicity of administering the AIMS combined with the easy interpretation of the scoring system must be considered when selecting an assessment tool.

Administration and scoring of the AIMS requires only 15 to 20 minutes and entails minimal handling of an infant. Administration of the MAI requires at least 30 to 35 minutes and requires extensive passive handling of the infant as well as positioning of an infant in artificial positions such as vertical and ventral suspension. The AIMS has a well-defined scoring system that can be interpreted easily to parents, while the risk point assignment used with the MAI is often confusing to parents. Perhaps the biggest advantage of the AIMS compared to the MAI is that it can be administered at any age and the score may be interpreted on the percentile graph, while risk points on the MAI can only be calculated at 4 and 8 months. At all other ages interpretation of the obtained scores is not possible. Comparison of the administration and scoring abilities of the two tests suggest that the AIMS is the more clinically useful screening tool. However, considering the better specificity values obtained on the MAI at 4 months, clinicians may choose to use both tests at this age, or at least assess primitive reflexes in isolation.

The PDGMS is not an acceptable screening tool to use with infants at risk

for motor dysfunction using traditional cut-off points. Its performance may be improved with further evaluation of different cut-offs.

5.4.3 Feasibility of early prediction of eventual motor abilities

The results of this study support the assumption that early motor abilities can be used to predict later motor abilities, and hence support the neuromaturational theory of motor development. However, clinicians must be cognizant of both the psychometric properties of a test and the constructs of motor development emphasized in a test. By matching the test constructs to the stage of motor development dominant at the age of assessment, the accuracy of prediction may be improved, especially the identification of normally developing infants.

The results also suggest that the previous experience of the clinicians is a contributing factor to accuracy of prediction. Training on test administration of gross motor measures often emphasizes the identification of abnormal responses. Clinicians may benefit from an opportunity to observe and assess normally developing infants in order to appreciate the wide variability of normal responses.

Accurate identification of infants with suspicious motor development remains problematic in the first year of life. The wide range of scores obtained by infants in this outcome classification suggests that present standardized tests of motor development cannot consistently accurately identify these infants at an early age. The inability to classify these infants correctly is most likely due to the heterogeneous nature of the motor skills exhibited by these infants at early ages. Because many infants in the suspicious category display similar motor abilities as those exhibited by normally developing infants, it may not be

possible to identify more suspicious infants without the misclassification of a significant proportion of the normally developing infants.

5.4.4 Research recommendations

In order to validate that the 10th and 5th percentile are the most accurate cut-offs on the AIMS at 4 and 8 months respectively, the predictive validity of the AIMS should be evaluated on another sample of at-risk infants. A multi-site, collaborative project would increase the sample size, and improve the standardization of motor assessments among follow-up clinics. In addition, the cut-offs should be evaluated at different assessment ages other than 4 and 8 months to examine the generalizability of these chosen cut-offs to other ages.

Further evaluation of the predictive validity of both the MAI and PDGMS is suggested, especially examination of alternate cut-off points. Results of the discriminant function analyses suggest that early scores on both of these tests can accurately classify infants' motor outcome at 18 months. Evaluation is necessary to separate the factors associated with poor psychometric design, such a improper cut-offs, from poor item selection.

The final recommendation for further research involves the suspicious group of infants. An outcome classification at 18 months is too early to accurately determine the eventual developmental status of children in this category. Studies with an outcome classification at an older age are necessary to fairly evaluate the predictive abilities of infant motor measures with this group of infants.

5.5.0 Summary

The results of this study are encouraging to clinicians who are interested in the early detection of motor dysfunction since the data suggest that early

identification of infants with normal and abnormal motor skills is feasible without a high rate of misclassification of normally developing infants. Confidence in the accuracy of early identification is imperative both to justify early treatment and to evaluate its effects. However, the results also suggest that screening for motor dysfunction with at-risk infants is a complex, multi-faceted endeavor. Traditional cut-offs may not always be the most appropriate choice, and different cut-offs may apply at different ages of development. As well as the psychometric properties of a measure, the fit between the motor constructs measured by the test and the developmental stage of an infant must be considered. These findings present additional challenges to physical and occupational therapists who are only recently becoming comfortable with using standardized tests in the assessment process. The findings of the study emphasize that merely using standardized tests is not sufficient; evaluation of the use of the measures in different situations and with different populations is imperative to improve screening accuracy. Accurate screening represents the cornerstone for the evaluation of treatment with at-risk infants; unless researchers and clinicians are confident that the appropriate infants are being identified, the evaluation of treatment effects is not possible.

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Appendix A

Informed Consent Form

CONSENT FORM

Investigators: Dr. M. Piper, Johanna Darrah, Dr. Paul Byrne, Dr. M. Joseph Watt

Predictive Validity of the Alberta Infant Motor Scale

I have been told that the purpose of this study is to evaluate the ability of the Alberta Infant Motor Scale (AIMS) to predict the movement ability of infants at 18 months of age compared with two other motor assessments, the Movement Assessment of Infants (MAI) and the Peabody Gross Motor Scale.

I understand that my child's motor development will be assessed by a physical therapist at 4 and 8 months adjusted ages and by a pediatrician at 18 months adjusted age. Adjusted age is the age of your child had he/she been born when expected. Each assessment will take approximately forty-five (45) minutes and will take place at the Faculty of Rehabilitation Medicine, University of Alberta.

I understand that my participation in this study is voluntary and I may withdraw my consent at any time without affecting any treatment or services my child receives. I also understand that this study is not part of the Follow-up Clinic and that my child is expected to attend the Follow-up Clinic in addition to this study.

I have been assured that all the information gathered throughout the study will be confidential and that no information will be released that would disclose the identity of my child.

I have been informed of the purpose of the study, the measurement procedures, and the duration of the study.

I have read and understand the information stated above and I sign this consent form willingly.

Any further questions concerning the study can be answered by contacting Dr. Martha Piper (492-5991) or Johanna Darrah (492-4939).

_____ _____

Signature of Parent/Guardian Date

_____ _____

Signature of Witness Date

_____ _____

Signature of Investigator Date

Alberta Infant Motor Scale

The Faculty of Rehabilitation Medicine at the University of Alberta has developed the Alberta Infant Motor Scale (AIMS), a new scale for assessing motor development in babies from birth to the age of walking. We are presently evaluating the ability of the Alberta Infant Motor Scale to identify babies that may have difficulty acquiring motor skills such as sitting, crawling or walking.

Each baby enrolled in the study will be assessed by a physical therapist at four and eight months adjusted ages. During the assessment, your baby's movements will be observed in different positions (such as lying on the tummy or the back) in order that we might see how he/she moves. We also will be recording the development of certain motor skills such as rolling over, sitting up, crawling and walking. Feedback concerning the assessment will be provided to you.

A pediatrician will also assess your baby at eighteen months adjusted age. All the assessments will be performed at the Faculty of Rehabilitation Medicine, University of Alberta. Each assessment will take approximately 30 minutes.

We believe that the information gathered from these assessments will help us determine whether the Alberta Infant Motor Scale is a useful assessment tool for use in neonatal follow-up clinics to identify infants with motor problems.

Your decision whether or not to participate in the study will in no way affect the other treatment or services your child receives. It goes without saying that we would like you to understand thoroughly what we are doing, so we welcome your questions. If you require additional information about the study you may contact one of the following people:

Dr. Martha Piper, Dean
Faculty of Rehabilitation Medicine
University of Alberta. 492-5991

Johanna Darrah
Faculty of Rehabilitation Medicine
University of Alberta. 492-4939

Participation is free of charge.

University
of Alberta

Appendix B

Sample Items and Descriptions of the Alberta Infant Motor Scale, Movement Assessment of Infants, Peabody Gross Motor Scale

Alberta Infant Motor Scale

The AIMS is an observational measure of infant gross motor development. It has been normed on a representative sample of 2202 infants born in Alberta.

Population: Infants 0 to 18 months

Time to Complete: 15 to 25 minutes

Scoring: Each item is assessed in terms of the posture the infant assumes, the weightbearing portions of the body and the antigravity or voluntary movement the infant must demonstrate to pass the item. An infant is observed and, for each of the four subscales, the least mature response observed and the most mature response observed are noted. These items and all those items between these two items represent the infant's 'motor window'. Each of these items is marked 'observed' or 'not observed'. An infant receives one point for each item before the least mature response and one point for each item in the motor window scored 'observed'. The scores for each of the four subscales are summed to achieve a total score.

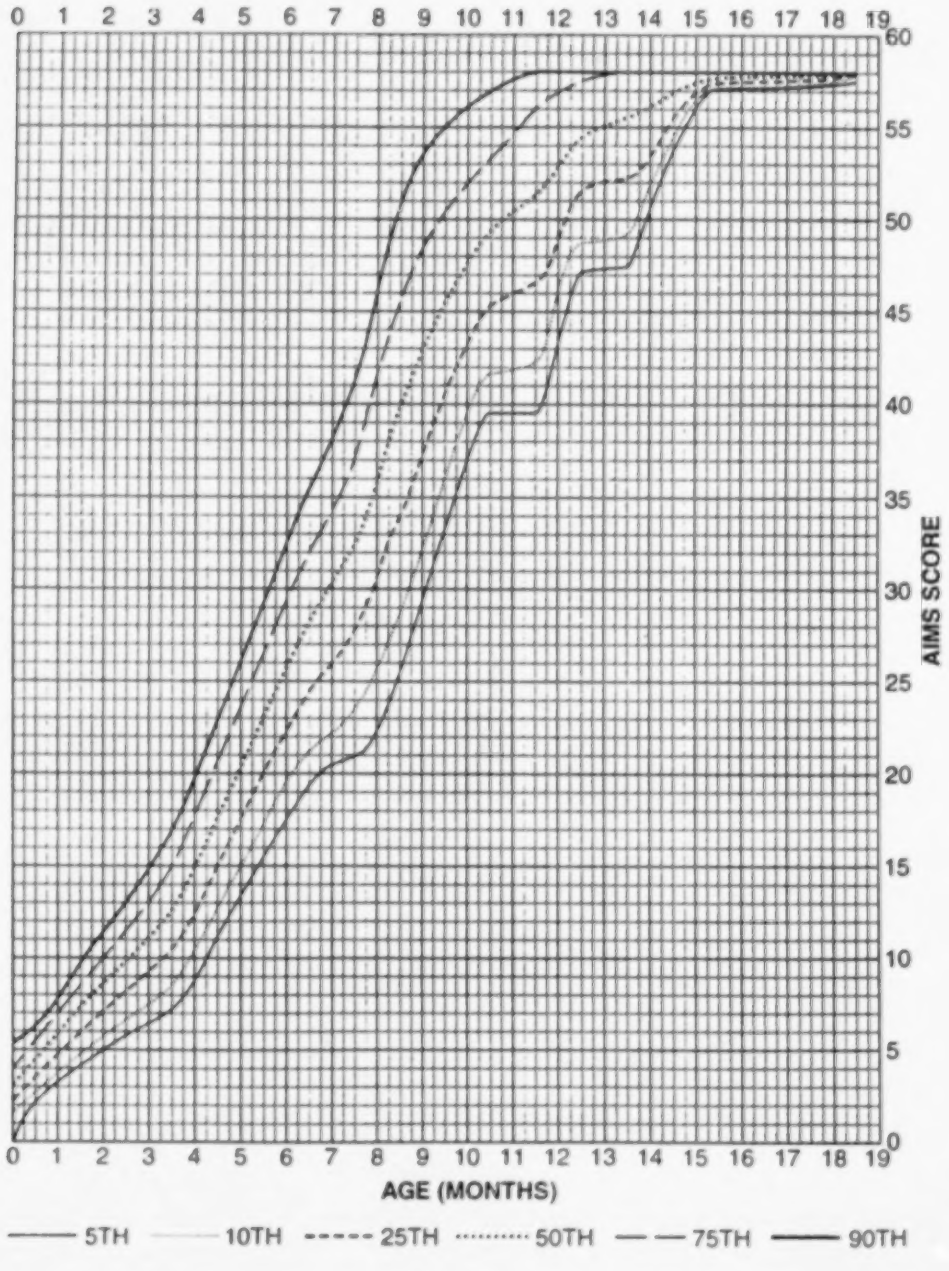
Sample Item

Pivoting

Weight Bearing	Weight on trunk, arms, and hands
Posture	Head to 90° Legs abducted and externally rotated
Antigravity Movement	Pivots Movement in arms and legs Lateral trunk flexion
To pass this item, the infant must use both arms and legs to pivot.	
Prompt: Place toy laterally to initiate movement.	

Percentile Graph from AIMS Scoresheet

Percentile Ranks



Movement Assessment of Infants

The Movement Assessment of Infants has been developed as a screening tool to identify and evaluate the motor function of high risk infants.

Population: Infants 0 to 12 months

Time to Complete: Maximum time of 1.5 hours to test and score. Average time of completion is 30 to 45 minutes.

Scoring: Muscle tone section scored on a 6 point bi-directional scale, with 3 representing normal tone, higher scores representing increasing degrees of hypertonia and lower scores increasing degrees of hypotonia. The items in the remaining three subscales are scored on a 4-point unidirectional scale, with 1 representing the most mature response and 4 the least mature. The presence of asymmetry is noted. For assessments at 4 and 8 months, an infant's responses can be compared to a 'high-risk' profile compiled by the authors. The number of high risk points accrued by an infant are used to designate risk status.

Sample Item

Active Use of Hips.

With the child supine, observe the spontaneous movements of the child's hips.

1 — Child rounds buttocks off the mat and easily plays with knees; child kicks legs together and reciprocally.
2 — Child can round buttocks off the mat but does not play with knees; child kicks legs together and reciprocally.
3 — Child kicks but does not round buttocks off the mat.
4 — Child shows minimal movement of the lower extremities.

Peabody Developmental Gross Motor Scale

This gross motor scale is one half of the Peabody Developmental Motor Scale, the other half assesses fine motor development. The Peabody was developed to identify children with delayed of aberrant motor development relative to a normative group. Norms were generated on 617 children.

Population: Children 0 to 83 months

Time to Complete: 30 to 35 minutes.

Scoring: Each item is graded on criterion performance with explicit instructions regarding the number of trials allowed and the amount of time allowed for completion of the skill. Scoring is on a 3-point ordinal scale, with 0 representing an unsuccessful attempt of an item, 1 = partial success, and 2 = successful attempt with all criteria met.

Sample Item

43. (D) Crawling	stomach	Place *toy* five feet in front of child. *Criterion:* Moves a distance of five feet, using both arms and legs in contact with surface.

Appendix C

Raw Test Scores and Values of Perinatal Variables for Infants in each Outcome Classification (Normal, Suspicious, Abnormal)

INFANTS WITH NORMAL CLASSIFICATION AT 18 MONTHS (N=100)

ID	GENDER	BW	GA	DAYSIN	APGAR1	APGAR5	VENT	SEIZURES	PVL	BPD	IVH	HIE	SIZE	MUSCLE4	PRIM4	AUTO4	VOLIT4	TRS4
1	1	1220	28	65	8	9	1	0	0	0	0	0	1	3	0	1	2	6
5	2	620	22	131	6	7	4	0	0	1	1	0	1	1	2	0	0	3
6	1	1065	27	78	6	8	1	0	0	0	0	0	1	2	0	0	0	2
7	1	1075	27	87	7	8	4	0	0	1	2	0	1	3	1	4	1	9
8	2	1405	30	42	2	5	2	0	0	0	0	0	1	3	0	3	1	7
9	1	1120	27	59	5	6	4	0	0	0	3	0	1	0	0	0	0	0
10	2	1490	33	68	5	7	0	0	0	0	0	0	1	0	0	0	0	0
11	2	973	26	69	5	8	2	0	0	0	0	0	1	0	0	0	0	0
13	2	980	26	77	5	7	1	0	0	0	1	0	1	0	0	0	0	0
14	1	1445	34	24	7	8	0	0	0	0	0	0	1	1	1	2	1	5
15	2	1340	31	57	5	8	1	0	0	0	0	0	1	0	1	2	0	3
16	2	1040	28	59	8	9	0	0	0	0	0	0	1	0	0	1	0	1
17	1	1470	29	41	4	8	1	0	0	0	0	0	1	0	0	0	0	0
18	1	1365	30	56	1	6	0	0	0	0	0	0	1	2	1	1	1	5
19	2	690	27	128	3	7	4	0	0	1	0	0	2	0	0	0	0	0
22	1	952	31	58	4	8	3	0	0	0	0	0	2	0	0	0	0	0
23	2	1005	29	87	3	8	1	0	0	0	0	0	1	0	0	1	0	1
24	2	800	28	79	1	6	4	0	0	0	0	0	2	1	1	4	3	9
25	1	930	27	77	6	7	4	0	0	0	0	0	1	0	0	2	0	2
26	1	970	26	107	6	8	1	0	0	0	2	0	1	0	1	2	3	6
29	2	800	26	108	2	7	4	0	0	0	0	0	1	1	0	0	0	1
30	1	1300	32	61	8	8	0	0	0	0	0	0	2	0	0	0	0	0
31	1	1420	32	37	6	8	0	0	0	0	0	0	1	2	0	2	0	4
33	2	1240	28	80	6	8	4	0	0	1	1	0	1	1	0	1	2	4
37	2	498	25	134	7	8	4	0	0	1	2	0	2	0	2	2	1	5
38	2	1440	26	84	4	5	4	1	0	1	3	0	1	2	2	0	1	5
39	1	946	29	88	2	6	4	0	0	1	0	0	1	0	3	1	2	6
40	1	3240	40	6	2	8	1	1	0	0	0	1	1	0	0	1	0	1
43	2	1205	28	56	3	5	4	0	0	1	0	0	1	0	0	0	0	0
44	2	1205	28	56	6	9	4	0	0	1	1	0	1	0	0	0	0	0
47	2	710	25	139	3	5	4	0	0	1	2	0	1	2	0	2	3	7
48	1	724	25	107	4	6	4	0	0	1	2	0	1	1	1	2	0	4

ID	GENDER	BW	GA	DAYSIN	APGAR1	APGAR5	VENT	SEIZURES	PVL	BPD	IVH	HIE	SIZE	MUSCLE4	PRIM4	AUTO4	VOLIT4	TRS4
49	1	1385	32	36	9	9	0	0	0	0	0	0	1	4	1	0	0	5
51	2	996	29	59	3	8	4	0	0	1	0	0	1	0	1	0	0	1
54	2	1265	32	15	2	5	1	0	0	0	0	0	1	1	0	0	0	1
55	2	1015	32	52	7	8	0	0	0	0	0	0	2	4	0	1	3	8
57	1	896	25	94	4	7	4	0	0	1	2	0	1	3	0	2	0	5
58	2	1280	30	45	7	9	0	0	0	0	0	0	1	0	0	0	1	1
60	1	717	25	105	3	6	4	0	0	1	2	0	1	1	0	0	0	1
61	2	1280	28	68	3	6	4	0	1	1	0	0	1	0	0	1	0	1
62	2	1265	29	57	7	9	1	0	0	0	0	0	1	0	0	0	0	0
63	2	1280	28	73	6	8	0	0	0	0	0	0	1	3	1	1	1	5
64	1	1290	30	57	6	8	1	0	0	0	0	0	1	3	2	5	2	12
65	1	1040	29	69	5	8	1	0	0	0	0	0	1	0	0	2	2	4
66	1	680	23	143	5	8	4	0	0	1	2	0	1	0	2	2	1	5
69	2	1175	29	61	5	8	1	0	0	0	0	0	1	0	0	1	1	2
70	2	1135	29	61	3	7	1	0	0	0	0	0	1	0	0	0	1	1
71	1	1365	31	46	7	9	0	0	0	0	0	0	1	2	4	0	1	7
72	1	1800	30	50	2	4	2	1	0	0	0	0	1	4	2	1	1	7
74	1	1410	30	48	5	7	3	1	1	0	3	0	1	2	2	3	2	9
76	2	1485	32	41	3	7	1	0	0	0	0	0	1	0	1	0	0	1
77	2	1315	30	32	2	6	0	0	0	0	0	0	1	6	0	2	5	13
79	2	640	27	85	5	7	4	0	0	1	0	0	2	0	0	0	0	0
80	2	1450	30	46	3	7	1	0	0	0	0	0	1	1	1	2	0	4
82	1	1390	29	62	6	9	1	0	0	0	0	0	1	2	0	1	0	3
83	1	1370	28	55	5	6	1	0	0	0	1	0	1	0	0	1	0	1
84	1	1340	28	55	8	9	0	0	0	0	0	0	1	1	2	0	0	3
87	2	1420	31	45	8	9	1	0	0	0	0	0	1	0	0	0	0	0
88	2	1110	33	41	7	8	0	0	0	0	0	0	2	0	0	1	0	1
89	1	675	29	11	6	6	4	0	0	1	0	0	2	0	0	0	0	0
90	2	970	26	71	5	7	4	0	0	1	2	0	1	0	0	0	0	0
91	1	963	27	113	4	9	4	0	0	1	0	0	1	5	0	4	3	12
92	1	925	27	113	6	7	4	0	0	1	1	0	1	5	2	4	3	14
93	1	1400	30	57	6	7	3	0	0	1	2	0	1	2	1	3	2	8
95	2	525	23	125	3	5	4	1	0	1	1	0	1	4	3	4	6	17
96	2	1260	30	25	6	9	0	0	0	0	0	0	1	0	0	0	0	0

ID	GENDER	BW	GA	DAYSIN	APGAR1	APGAR5	VENT	SEIZURES	PVL	BPD	IVH	HIE	SIZE	MUSCLE4	PRIM4	AUTO4	VOLIT4	TRS4
102	2	1085	29	52	8	5	1	0	0	0	0	0	1	0	0	0	0	0
103	2	1280	30	45	9	9	0	0	0	0	0	0	1	0	0	0	1	1
104	1	1235	30	45	6	7	1	0	0	0	0	0	1	0	0	0	0	0
107	1	1200	31	54	7	8	1	0	0	0	0	0	1	1	1	4	1	7
108	2	1240	30	46	4	7	1	0	0	0	1	0	1	0	0	0	0	0
109	1	700	24	135	2	4	4	0	0	1	1	0	1	1	0	2	1	4
110	2	680	24	102	6	9	4	0	0	1	0	0	1	1	0	0	0	1
112	1	1405	29	72	3	6	1	0	0	0	0	0	1	0	0	0	0	0
115	2	3120	41	8	4	6	1	1	0	0	0	2	1	1	0	1	2	4
116	1	1400	29	49	1	7	1	0	0	0	0	0	1	0	0	0	0	0
117	1	1805	34	24	1	1	1	1	0	0	0	0	1	0	1	0	0	1
118	2	1010	26	66	4	9	2	0	0	0	0	0	1	3	0	1	0	4
119	1	850	28	68	6	8	3	0	0	0	0	0	2	1	0	2	0	3
120	2	1290	30	43	2	6	1	0	0	0	0	0	1	0	0	0	0	0
121	1	820	25	93	4	6	4	0	0	0	0	0	1	0	2	0	1	3
122	1	1110	27	66	1	6	4	0	0	1	0	0	1	1	0	1	0	2
123	2	1380	33	46	8	9	0	0	0	0	0	0	1	0	0	0	0	0
124	1	1460	31	42	6	8	2	0	0	0	0	0	1	0	0	1	1	2
125	1	1340	31	42	8	10	1	0	0	0	0	0	1	0	0	1	0	1
126	1	880	31	68	7	8	0	0	0	0	0	0	1	3	2	3	3	11
127	2	1395	32	59	7	9	0	0	0	0	0	0	1	0	0	0	0	0
128	1	670	24	97	5	7	4	0	0	1	1	0	1	5	3	1	1	10
129	2	1340	32	38	7	8	0	0	0	0	0	0	1	2	1	0	0	3
130	1	1410	30	51	6	8	0	0	0	0	1	0	1	1	2	1	0	4
131	1	1020	31	58	8	9	0	0	0	0	0	0	1	0	0	0	0	0
132	2	1080	28	67	5	7	4	0	0	0	0	0	1	0	0	0	0	0
134	2	803	31	53	8	9	0	0	0	0	0	0	2	0	0	0	0	0
136	2	1500	30	45	8	9	0	0	0	0	0	0	1	0	0	0	1	1
137	2	2240	39	7	5	7	1	0	0	0	0	2	2	2	0	0	0	2
138	1	1150	27	82	7	8	4	0	0	0	2	0	1	1	1	0	2	4
141	1	1435	30	47	6	8	1	0	0	0	0	0	1	0	0	0	0	0
142	2	1000	28	87	4	7	4	0	0	0	0	0	1	0	0	0	0	0
143	1	1120	27	65	7	9	1	0	0	0	1	0	1	1	0	1	0	2
144	1	647	29	47	7	9	4	0	0	0	0	0	2	2	0	2	0	4

ID	PRONE4	SUPINE4	SIT4	STAND4	TOTAL4	PRGRAPH4	REFLEX4	BALANCE4	NONLOC4	PEARS4	PEAPR4
1	5	4	1	1	11	11	15	4	24	43	9
5	6	6	2	3	17	52	21	6	31	58	35
6	6	4	2	0	12	26	20	4	27	51	22
7	1	4	1	2	8	1	20	2	15	37	2
8	3	4	1	2	10	15	20	3	25	48	86
9	8	5	4	2	19	88	21	6	36	63	97
10	5	5	2	2	14	50	21	6	30	57	35
11	6	6	2	2	16	60	20	3	32	55	30
13	6	4	1	2	13	25	20	4	30	54	24
14	3	4	1	2	10	10	20	2	22	44	76
15	6	4	3	2	15	50	21	3	28	54	24
16	6	4	3	2	15	50	19	4	27	50	19
17	6	5	2	1	14	50	18	4	26	48	86
18	2	4	2	2	10	10	20	2	25	47	13
19	6	6	3	3	18	75	21	4	33	58	35
22	6	4	3	2	15	50	20	4	27	51	22
23	5	5	2	2	14	50	20	5	32	57	35
24	4	3	0	1	8	1	20	0	12	32	2
25	3	5	3	2	13	26	20	5	27	52	22
26	6	4	1	2	13	25	19	4	26	49	88
29	6	5	3	2	16	60	20	3	27	50	88
30	9	7	8	3	27	99	23	11	38	74	81
31	3	4	1	2	10	10	20	3	26	49	19
33	2	3	3	2	10	5	20	2	23	45	11
37	2	4	1	2	9	5	20	2	17	39	2
38	5	4	2	1	12	12	20	2	24	46	11
39	5	3	2	2	12	26	20	1	26	47	86
40	5	4	3	2	14	46	20	4	25	49	88
43	4	7	2	2	15	50	20	3	26	49	19
44	3	4	2	2	11	14	20	3	25	48	13
47	2	3	1	2	8	8	20	2	19	41	71
48	4	5	2	2	13	26	20	5	26	51	22
49	5	4	2	2	13	37	20	5	28	53	97
51	3	4	2	2	11	13	20	3	28	51	22

ID	PRONE4	SUPINE4	SIT4	STAND4	TOTAL4	PRGRAPH4	REFLEX4	BALANCE4	NONLOC4	PEARS4	PEAPR4
54	6	5	3	2	16	56	20	5	28	53	24
55	2	4	3	2	11	17	20	2	24	46	81
57	3	4	1	2	10	10	20	2	22	44	9
58	6	5	3	2	16	55	20	4	26	50	19
60	6	5	3	3	17	72	20	3	27	50	19
61	5	4	3	2	14	40	20	2	27	49	88
62	6	6	3	2	17	75	20	5	30	55	97
63	3	5	3	2	13	27	20	2	28	50	19
64	3	5	2	2	12	25	20	2	24	46	11
65	5	5	1	2	13	27	20	2	20	42	6
66	5	3	2	2	12	8	20	1	24	45	11
69	3	5	3	3	14	40	20	2	26	48	13
70	3	5	3	3	14	40	20	2	25	47	13
71	5	4	2	2	13	27	22	2	28	52	22
72	6	4	1	2	13	27	20	3	21	44	9
74	3	4	1	1	9	5	17	2	20	39	2
76	6	5	3	2	16	62	20	2	31	53	97
77	3	3	1	1	8	3	18	1	19	38	55
79	7	5	3	2	17	66	20	3	26	49	19
80	5	4	3	2	14	44	20	2	24	46	11
82	6	4	2	2	14	37	20	2	22	44	76
83	6	5	2	2	15	50	21	2	29	52	22
84	6	4	2	2	14	42	21	2	28	51	22
87	4	4	4	3	15	50	20	5	28	53	24
88	7	5	2	2	16	58	21	4	29	54	24
89	4	4	1	2	11	17	20	3	26	49	88
90	6	6	4	2	18	82	20	6	30	57	97
91	1	3	1	1	6	0	20	2	19	41	71
92	1	5	1	1	8	4	20	2	20	42	71
93	4	4	1	1	10	10	20	2	22	44	9
95	5	3	1	1	10	10	20	1	17	38	22
96	8	7	3	3	21	99	21	5	34	62	97
102	6	5	2	3	16	60	20	4	30	54	24
103	5	3	2	2	12	25	20	2	26	48	13

ID	PRONE4	SUPINE4	SIT4	STAND4	TOTAL4	PRGRAPH4	REFLEX4	BALANCE4	NONLOC4	PEARS4	PEAPR4
104	5	4	2	2	13	33	20	2	28	50	19
107	1	3	1	2	7	1	20	2	18	40	2
108	5	5	3	2	15	50	20	6	26	52	22
109	3	4	1	2	10	10	20	2	20	42	71
110	7	5	3	2	17	65	21	6	35	62	56
112	7	6	3	2	18	75	21	7	33	63	65
115	4	3	3	2	12	25	20	4	25	49	19
116	4	4	3	3	14	40	20	2	25	47	13
117	5	5	2	2	14	41	20	5	28	53	24
118	5	5	1	1	12	25	20	2	19	41	6
119	5	6	3	2	16	60	20	3	28	51	22
120	5	4	1	3	13	29	20	3	29	52	22
121	6	3	3	2	14	50	21	2	26	49	88
122	6	4	3	2	15	50	20	4	25	49	19
123	5	4	3	2	14	40	20	5	28	53	24
124	5	4	1	2	12	25	20	2	24	46	11
125	6	4	1	2	13	29	20	2	27	49	19
126	3	4	1	2	10	8	20	1	24	45	81
127	5	5	4	2	16	62	20	6	33	59	44
128	4	6	1	2	13	30	20	2	23	45	11
129	7	5	3	2	17	70	21	2	29	52	22
130	5	5	1	2	13	30	20	2	24	46	11
131	6	5	3	2	16	60	20	6	35	61	56
132	7	6	2	2	17	70	20	4	26	52	22
134	5	4	2	1	12	22	20	3	25	48	13
136	5	6	2	3	16	60	20	4	27	51	22
137	7	8	3	2	20	68	21	6	35	64	65
138	5	4	3	2	14	37	21	3	26	50	19
141	5	4	4	2	15	50	20	5	31	56	30
142	8	7	3	3	21	90	21	6	34	63	65
143	5	6	4	2	17	66	20	2	26	48	13
144	2	4	2	1	9	5	20	2	27	49	19

ID	MUSCLE8	PRIM8	AUTO8	VOLIT8	TRS8	PRONE8	SUPINE8	SIT8	STAND8	TOTAL8	PRGRAPH8
1	0	0	1	1	2	12	8	10	3	33	38
5	0	0	0	0	0	18	9	10	8	45	88
6	0	0	0	1	1	15	9	10	2	36	50
7	4	1	6	8	19	5	7	7	1	20	4
8	3	0	1	3	7	11	8	5	2	26	10
9	0	0	0	0	0	16	9	10	8	43	80
10	0	0	1	1	2	12	9	10	3	34	38
11	0	0	0	0	0	18	9	10	5	42	75
13	0	0	0	1	1	14	9	10	3	36	50
14	5	0	4	5	14	9	9	9	2	29	25
15	0	0	0	0	0	20	9	10	5	44	85
16	0	0	0	0	0	20	9	12	8	49	90
17	0	0	2	1	3	13	9	10	3	35	50
18	0	0	1	2	3	14	9	10	3	36	50
19	1	0	0	0	1	17	9	11	4	41	75
22	3	0	0	0	3	17	9	10	4	40	72
23	0	0	0	0	0	20	9	10	10	49	90
24	3	0	4	3	10	11	8	7	2	28	20
25	1	1	0	0	2	15	9	10	3	37	52
26	0	0	4	5	9	14	9	4	3	30	25
29	0	0	0	1	1	16	8	8	3	35	50
30	0	0	0	0	0	16	9	10	4	39	68
31	0	0	0	2	2	13	9	10	3	35	50
33	0	1	1	4	6	10	7	9	3	29	18
37	3	1	6	7	17	5	7	6	2	20	2
38	2	1	2	7	12	11	8	7	2	28	17
39	4	3	3	5	15	12	8	3	2	25	10
40	4	0	4	5	13	12	8	5	2	27	12
43	0	0	0	0	0	19	9	11	9	48	90
44	0	0	0	0	0	20	9	11	6	46	90
47	0	0	3	4	7	13	8	5	3	29	20
48	3	0	3	5	11	8	8	7	3	26	10
49	2	0	4	2	8	12	8	8	3	31	25
51	0	0	1	3	4	15	9	8	3	35	44

ID	MUSCLE8	PRIM8	AUTO8	VOLIT8	TRS8	PRONE8	SUPINE8	SIT8	STAND8	TOTAL8	PRGRAPH8
54	0	0	0	1	1	12	8	10	3	33	37
55	2	0	1	1	4	13	9	10	3	35	50
57	2	0	4	4	10	13	8	8	3	32	27
58	2	0	1	3	6	16	9	6	3	34	43
60	0	1	1	0	2	18	9	10	5	42	75
61	0	0	1	3	4	14	9	8	3	34	43
62	0	0	1	0	1	20	9	12	9	50	88
63	0	0	0	0	0	16	9	9	8	42	75
64	0	0	1	2	3	12	9	9	3	33	37
65	0	0	4	5	9	12	9	6	3	30	25
66	2	0	6	8	16	7	5	1	3	16	1
69	2	0	0	3	5	13	7	10	3	33	37
70	0	0	3	3	6	11	7	8	3	29	22
71	3	0	1	2	6	11	9	9	3	32	37
72	0	1	1	0	2	14	9	10	3	36	50
74	3	0	4	4	11	12	8	6	3	29	21
76	1	0	2	1	4	12	9	10	3	34	43
77	1	0	1	1	3	10	9	10	2	31	25
79	0	0	0	1	1	16	9	10	6	41	75
80	0	0	0	0	0	19	9	12	6	46	90
82	0	0	1	0	1	16	9	10	6	41	75
83	0	0	2	3	5	15	9	6	3	33	25
84	0	0	2	3	5	15	9	6	2	32	24
87	0	0	0	0	0	18	9	10	8	45	79
88	0	1	2	5	8	15	9	3	3	30	25
89	0	0	1	1	2	14	8	9	3	34	45
90	0	0	1	2	3	15	9	10	3	37	55
91	4	1	3	11	19	4	7	3	2	16	0
92	4	0	5	8	17	8	8	3	0	19	0
93	3	0	5	7	15	7	6	4	3	20	0
95	3	4	2	7	16	8	8	7	2	25	9
96	1	0	1	0	2	15	9	9	8	41	75
102	0	0	0	0	0	16	8	10	4	38	60
103	1	0	5	2	8	13	8	8	3	32	32

ID	MUSCLE8	PRIM8	AUTO8	VOLIT8	TRS8	PRONE8	SUPINE8	SIT8	STAND8	TOTAL8	PRGRAPH8
104	2	0	6	5	13	7	7	8	3	25	8
107	0	0	5	5	10	8	7	8	3	26	10
108	0	0	1	1	2	15	9	9	3	36	45
109	4	0	4	5	13	13	8	5	2	28	18
110	2	0	1	0	3	18	8	10	6	42	75
112	1	0	0	3	4	13	9	9	4	35	50
115	3	0	2	7	12	8	8	6	2	24	7
116	0	0	0	0	0	15	9	10	7	41	72
117	2	0	2	3	7	7	8	8	3	26	11
118	3	0	3	3	9	11	9	9	3	32	32
119	0	0	3	7	10	13	9	6	3	31	20
120	1	0	0	0	1	15	9	10	3	37	50
121	0	0	1	1	2	16	8	8	3	35	47
122	0	0	0	2	2	10	9	8	3	30	22
123	1	0	2	3	6	14	8	9	3	34	40
124	0	0	1	2	3	9	8	8	3	28	18
125	0	0	5	4	9	9	7	8	3	27	15
126	2	2	8	5	17	9	7	6	3	25	9
127	2	0	1	3	6	15	9	6	3	33	37
128	0	0	2	4	6	12	8	4	3	27	30
129	2	0	0	0	2	19	9	10	7	45	97
130	0	0	1	2	3	9	8	9	3	29	17
131	0	0	0	0	0	17	9	10	5	41	73
132	2	0	0	0	2	20	7	12	10	49	88
134	3	0	0	0	3	17	9	9	5	40	70
136	0	0	1	0	1	20	9	10	9	48	90
137	2	0	0	0	2	19	9	10	7	45	88
138	0	0	0	1	1	9	8	10	3	30	22
141	0	0	2	2	4	12	9	7	3	31	27
142	4	0	0	0	4	14	9	10	9	42	75
143	0	0	2	3	5	14	9	7	3	33	37
144	1	0	2	3	6	12	8	7	3	30	25

ID	REFLEX8	BALANCE8	NONLOC8	LOC8	PEARS8	PEAPR8	BAYLEYRS	BAYPDI	NEURO18
1	24	14	46	8	92	57	53	97	0
5	24	15	62	17	119	77	60	124	0
6	24	14	52	10	100	14	53	98	0
7	22	8	36	0	66	7	52	84	0
8	22	8	48	2	80	1	57	113	0
9	24	17	62	16	119	77	59	120	0
10	24	14	51	7	96	5	61	129	0
11	24	15	61	14	114	89	56	107	0
13	24	15	59	11	109	48	51	81	0
14	23	13	40	4	80	1	59	120	0
15	24	15	62	14	115	66	54	90	0
16	24	17	62	18	122	80	60	124	0
17	24	14	52	6	96	5	69	75	0
18	24	14	51	5	94	2	54	94	0
19	24	14	61	12	111	57	55	100	0
22	24	14	62	14	114	89	50	86	0
23	24	18	62	16	120	77	55	96	0
24	22	12	44	2	80	24	53	88	0
25	24	14	55	10	103	34	52	84	0
26	22	7	50	6	85	1	48	72	0
29	23	9	50	9	91	1	76	103	0
30	24	14	59	13	110	48	56	107	0
31	24	14	53	4	95	5	74	90	0
33	23	14	49	0	86	1	75	94	0
37	22	6	34	1	63	7	76	98	0
38	24	14	47	6	91	57	72	82	0
39	22	8	48	2	80	1	67	67	0
40	22	9	46	2	79	24	73	86	0
43	24	18	62	18	122	80	71	83	0
44	24	15	62	16	117	71	77	107	0
47	22	8	46	7	83	33	72	82	0
48	22	7	44	2	75	15	77	102	0
49	24	12	51	2	89	1	77	102	0
51	23	12	50	9	94	2	73	91	0

ID	REFLEX8	BALANCE8	NONLOC8	LOC8	PEARS8	PEAPR8	BAYLEYRS	BAYPDI	NEURO18
54	24	13	52	6	95	63	70	79	0
55	24	14	53	4	95	5	75	94	0
57	23	10	46	2	81	1	75	94	0
58	22	10	56	10	98	9	74	95	0
60	24	14	57	12	107	87	.	.	0
61	23	11	50	8	92	57	74	95	0
62	24	18	61	16	121	80	77	107	0
63	24	16	57	16	113	62	75	99	0
64	24	14	52	10	100	14	74	95	0
65	23	9	47	4	83	33	72	87	0
66	21	3	31	1	56	2	69	66	0
69	24	14	50	0	88	1	72	82	0
70	24	14	47	0	85	1	72	82	0
71	24	14	49	8	95	63	72	78	0
72	24	14	49	8	95	5	73	91	0
74	21	8	45	3	77	19	70	74	0
76	24	14	49	7	94	2	76	103	0
77	24	14	45	6	89	1	75	90	0
79	24	16	61	12	113	62	75	90	0
80	24	15	61	15	115	66	74	90	0
82	24	14	59	16	113	62	75	94	0
83	22	7	49	8	86	1	75	99	0
84	22	7	47	8	84	1	73	91	0
87	24	16	61	18	119	77	75	94	0
88	22	6	49	8	85	1	74	90	0
89	23	13	51	6	93	57	74	90	0
90	23	14	49	8	94	2	73	86	0
91	22	6	36	0	64	1	70	79	0
92	21	7	39	3	70	1	72	87	0
93	22	7	43	0	72	1	74	95	0
95	23	11	46	3	83	1	66	63	0
96	24	16	61	15	116	66	75	106	0
102	24	14	61	14	113	62	76	103	0
103	24	14	51	3	92	1	74	90	0

ID	REFLEX8	BALANCE8	NONLOC8	LOC8	PEARS8	PEAPR8	BAYLEYRS	BAYPDI	NEURO18
104	24	14	47	0	85	1	72	82	0
107	23	13	43	0	79	1	.	.	0
108	23	14	52	9	98	9	73	91	0
109	22	7	46	3	78	1	69	75	0
110	23	15	58	11	107	41	73	91	0
112	24	13	51	8	96	5	73	91	0
115	22	11	41	2	76	19	66	63	0
116	24	14	61	15	114	62	75	99	0
117	23	14	44	2	83	1	72	87	0
118	24	14	47	6	91	1	75	90	0
119	22	7	44	8	81	1	70	74	0
120	24	14	57	10	105	38	76	103	0
121	23	14	50	9	96	5	72	87	0
122	24	14	46	4	88	1	75	99	0
123	23	14	50	6	93	2	76	103	0
124	23	14	46	2	85	1	71	83	0
125	23	14	48	1	86	1	72	87	0
126	20	11	45	2	78	1	74	86	0
127	23	8	45	4	80	1	73	86	0
128	22	6	47	6	81	24	71	83	0
129	24	14	58	12	108	87	75	99	0
130	23	14	52	2	91	1	72	82	0
131	24	14	59	13	110	48	73	91	0
132	24	16	62	16	120	77	73	91	0
134	23	14	58	10	105	38	72	87	0
136	24	16	62	18	121	80	75	99	0
137	24	15	62	16	117	71	74	95	0
138	24	14	50	3	91	1	75	99	0
141	22	8	47	8	85	1	76	103	0
142	24	16	62	16	118	71	76	103	0
143	23	11	50	8	92	1	73	91	0
144	23	12	46	2	83	1	74	95	0

INFANTS WITH SUSPICIOUS CLASSIFICATION AT 18 MONTHS (N=9)

ID	GENDER	BW	GA	DAYSIN	APGAR1	APGAR5	VENT	SEIZURES	PVL	BPD	IVH	HIE	SIZE	MUSCLE4	PRIM4	AUTO4	VOLIT4	TRS4
2	2	929	27	115	2	5	4	0	0	1	3	0	1	6	2	5	10	23
21	1	1110	27	35	5	8	1	0	0	0	0	0	1	5	0	3	3	11
28	1	802	25	105	4	8	4	0	1	1	4	0	1	0	1	0	0	1
35	1	860	27	104	5	8	4	1	0	0	0	0	1	3	2	0	2	7
36	2	870	27	83	4	9	4	1	0	0	0	0	1	2	0	2	3	7
46	2	1125	26	136	7	7	4	1	1	1	0	0	1	0	0	0	0	0
85	1	1005	29	40	3	5	1	0	0	0	0	0	1	0	0	3	2	5
105	2	590	23	125	1	7	4	0	0	1	2	0	1	0	1	0	0	1
114	1	1450	34	25	7	8	0	0	0	0	0	0	1	0	0	1	0	1

ID	PRONE4	SUPINE4	SIT4	STAND4	TOTAL4	PRGRAPH4	REFLEX4	BALANCE4	NONLOC4	PEARS4	PEAPR4
2	0	0	0	1	1	0	2	0	5	7	2
21	2	3	1	1	7	1	20	0	20	40	62
28	4	4	2	2	12	25	20	4	29	53	97
35	5	3	2	0	10	10	19	4	21	44	9
36	4	3	1	1	9	5	20	3	19	42	6
46	7	6	3	2	18	75	20	5	30	55	30
85	6	4	1	1	12	25	19	4	24	47	13
105	5	5	3	2	15	50	20	3	27	50	19
114	6	6	3	2	17	66	20	6	35	61	56

ID	MUSCLE8	PRIM8	AUTO8	VOLIT8	TRS8	PRONE8	SUPINE8	SIT8	STAND8	TOTAL8	PRGRAPH8
2	7	3	12	18	40	2	5	1	1	9	0
21	3	2	10	7	22	5	6	3	1	15	0
28	0	0	0	3	3	6	8	9	3	26	10
35	3	5	8	9	25	9	6	7	2	24	7
36	6	5	10	11	32	5	7	5	2	19	0
46	0	0	0	0	0	11	8	9	3	31	25
85	3	0	6	4	13	11	8	6	2	27	18
105	2	1	3	1	7	14	8	8	2	32	35
114	1	0	6	5	12	9	8	4	2	23	3

ID	REFLEX8	BALANCE8	NONLOC8	LOC8	PEARS8	PEAPR8	BAYLEYRS	BAYPDI	NEURO18
2	16	2	21	0	39	1	44	53	1
21	18	6	32	0	56	2	44	60	1
28	24	14	50	4	92	1	72	87	1
35	23	12	42	2	79	24	67	62	1
36	22	8	33	4	67	7	67	62	1
46	24	14	49	3	90	1	71	78	1
85	20	11	44	4	79	1	71	83	1
105	23	13	50	7	93	2	66	63	1
114	22	7	44	2	75	1	59	50	1

INFANTS WITH ABNORMAL CLASSIFICATION AT 18 MONTHS (N=16)

ID	GENDER	BW	GA	DAYSIN	APGAR1	APGAR5	VENT	SEIZURES	PVL	BPD	IVH	HIE	SIZE	MUSCLE4	PRIM4	AUTO4	VOLIT4	TRS4
12	1	630	26	132	1	3	4	0	0	1	3	0	1	5	1	4	2	12
20	1	2080	38	53	4	7	4	1	0	1	4	2	2	6	3	8	11	28
27	2	530	24	219	1	3	4	1	0	1	4	0	1	5	4	6	9	24
45	1	2445	36	39	0	1	1	1	0	0	0	0	1	7	9	8	13	37
52	2	3025	38	27	3	6	4	1	1	0	1	2	1	7	2	6	8	23
59	2	887	27	120	6	7	4	0	1	1	2	0	1	4	2	6	5	17
67	2	1100	28	68	7	8	4	0	1	0	2	0	1	6	9	5	10	30
68	2	740	24	117	.	2	4	1	0	1	4	0	1	5	2	3	4	14
75	1	871	26	94	2	6	4	0	1	1	3	0	1	2	4	4	3	13
81	1	380	29	343	5	8	4	0	0	1	0	0	2	6	2	6	10	24
86	1	3250	41	21	0	1	2	1	0	0	0	2	1	6	5	3	8	22
113	1	1260	27	77	1	4	4	0	1	1	2	0	1	4	8	0	2	14
139	1	1080	27	80	6	7	4	1	0	1	0	0	1	2	0	1	0	3
140	1	1060	27	91	6	7	4	0	0	0	0	0	1	0	1	0	2	3
151	1	1365	29	34	6	7	1	0	0	0	1	0	1	2	8	3	0	13
160	2	1090	28	56	1	6	4	1	0	0	4	0	1	3	3	1	4	11

ID	PRONE4	SUPINE4	SIT4	STAND4	TOTAL4	PRGRAPH4	REFLEX4	BALANCE4	NONLOC4	PEARS4	PEAPR4
12	2	4	1	1	8	1	20	2	20	42	6
20	2	0	0	1	3	0	12	0	0	12	2
27	2	3	0	1	6	0	20	0	11	31	29
45	0	0	0	0	0	0	7	0	3	10	0
52	3	0	0	1	4	0	13	0	8	21	2
59	2	4	1	1	8	3	20	1	15	36	2
67	2	0	1	2	5	0	14	0	16	30	2
68	2	4	1	2	9	5	18	1	18	37	2
75	3	3	2	2	10	10	19	1	24	44	9
81	0	0	1	1	2	0	3	0	6	9	3
86	0	2	2	2	6	0	18	1	15	34	2
113	5	2	3	0	10	10	20	3	24	47	13

ID	PRONE4	SUPINE4	SIT4	STAND4	TOTAL4	PRGRAPH4	REFLEX4	BALANCE4	NONLOC4	PEARS4	PEAPR4
139	6	6	1	2	15	50	20	4	31	57	35
140	5	3	2	2	12	23	20	3	28	51	22
151	5	4	1	0	10	8	20	2	21	43	9
160	3	3	2	2	10	8	20	1	23	44	9

ID	MUSCLE8	PRIM8	AUTO8	VOLIT8	TRS8	PRONE8	SUPINE8	SIT8	STAND8	TOTAL8	PRGRAPH8
12	5	5	11	13	34	6	5	2	2	15	0
20	6	4	14	21	45	2	2	0	0	4	0
27	4	2	9	13	28	5	6	2	2	15	0
45	7	6	14	21	48	2	0	0	0	2	0
52	7	9	14	21	51	3	0	0	0	3	0
59	6	0	8	11	25	5	4	3	2	14	0
67	6	10	12	21	49	1	0	1	0	2	0
68	6	6	10	13	35	3	3	3	2	11	0
75	6	8	12	12	38	8	4	8	2	22	5
81	6	2	14	16	38	3	4	1	2	10	0
86	6	9	14	19	48	2	2	1	0	5	0
113	6	7	12	11	36	6	5	2	2	15	0
139	5	3	7	7	22	9	8	2	2	21	4
140	2	3	4	7	16	10	8	3	1	22	5
151	4	7	8	7	26	9	5	3	0	17	0
160	6	4	13	14	37	6	4	4	2	16	0

ID	REFLEX8	BALANCE8	NONLOC8	LOC8	PEARS8	PEAPR8	BAYLEYRS	BAYPDI	NEURO18
12	21	3	26	0	50	0	34	50	2
20	10	0	4	0	14	1	.	.	2
27	21	5	35	2	63	1	46	50	2
45	9	0	2	0	11	0	.	.	2
52	11	0	7	0	18	2	.	.	2
59	19	4	30	0	53	1	58	50	2

ID	REFLEX8	BALANCE8	NONLOC8	LOC8	PEARS8	PEAPR8	BAYLEYRS	BAYPDI	NEURO18
67	18	0	13	0	31	1	18	.	2
68	18	2	28	0	48	1	53	.	2
75	22	11	39	0	72	9	61	50	2
81	20	2	21	0	43	1	32	49	2
86	20	0	16	0	36	1	7	49	2
113	17	4	29	0	50	1	38	50	2
139	22	5	43	6	76	1	55	50	2
140	22	6	41	5	74	1	50	50	2
151	22	7	38	2	69	1	56	50	2
160	21	5	29	0	55	1	.	.	2

Appendix D

Diagnoses for Infants in Abnormal and Suspicious Outcome Classifications

DIAGNOSIS OF INFANTS IN SUSPICIOUS CATEGORY

ID	DIAGNOSIS
2	Developmental delay
21	Developmental delay
28	Increased tone
35	Toe walker
36	Mild increased tone lower limbs, strabismus
46	Increased muscle tone, sustained clonus
85	Increased muscle tone
105	Gross motor delay
114	Developmental delay, decreased deep tendon reflexes, questionable microcephaly

DIAGNOSIS OF INFANTS IN ABNORMAL CATEGORY

ID	DIAGNOSIS
12	Spastic diplegia
20	Spastic quadriplegia, microcephaly, blind, hearing impaired
27	Spastic diplegia
45	Spastic quadriplegia (deceased at 2 years of age)
52	Athetoid quadriplegia
59	Spastic diplegia, developmental delay
67	Athetoid cerebral palsy
68	Mild spastic quadriplegia, visual impairment
75	Triplegic cerebral palsy
81	Gross developmental delay, hypotonic cerebral palsy, mental retardation
86	Spastic athetoid cerebral palsy
113	Spastic quadriplegia
139	Spastic diplegia
140	Spastic diplegia
151	Spastic diplegia
160	Spastic triplegia

Appendix E

Sensitivity, Specificity, Positive Predictive Value, Negative Predictive Value for AIMS Percentile Ranks, 0 to 25

AIMS: ABNORMAL VS NORMAL/SUSPICIOUS AT 4 MONTHS ADJUSTED AGE												
	16	9	100	125								
% Rank	ABN	SUS	NORM		a cell	b cell	c cell	d cell	Sensitivity	Specificity	+PV	-PV
0	7	1	1		7	2	9	107	43.8%	98.2%	77.8%	92.2%
1	8	2	4		8	6	8	103	50.0%	94.5%	57.1%	92.8%
2	8	2	4		8	6	8	103	50.0%	94.5%	57.1%	92.8%
3	9	2	5		9	7	7	102	56.2%	93.6%	56.2%	93.6%
4	9	2	6		9	8	7	101	56.2%	92.7%	52.9%	93.5%
5	10	3	10		10	13	6	96	62.5%	88.1%	43.5%	94.1%
6	10	3	10		10	13	6	96	62.5%	88.1%	43.5%	94.1%
7	10	3	10		10	13	6	96	62.5%	88.1%	43.5%	94.1%
8	12	3	13		12	16	4	93	75.0%	85.3%	42.9%	95.9%
9	12	3	13		12	16	4	93	75.0%	85.3%	42.9%	95.9%
10	14	4	20		14	24	2	85	87.5%	78.0%	36.8%	97.7%
11	14	4	21		14	25	2	84	87.5%	77.1%	35.9%	97.7%
12	14	4	22		14	26	2	83	87.5%	76.1%	35.0%	97.6%
13	14	4	23		14	27	2	82	87.5%	75.2%	34.1%	97.6%
14	14	4	24		14	28	2	81	87.5%	74.3%	33.3%	97.6%
15	14	4	25		14	29	2	80	87.5%	73.4%	32.6%	97.6%
16	14	4	25		14	29	2	80	87.5%	73.4%	32.6%	97.6%
17	14	4	27		14	31	2	78	87.5%	71.6%	31.1%	97.5%
18	14	4	27		14	31	2	78	87.5%	71.6%	31.1%	97.5%
19	14	4	27		14	31	2	78	87.5%	71.6%	31.1%	97.5%
20	14	4	27		14	31	2	78	87.5%	71.6%	31.1%	97.5%
21	14	4	27		14	31	2	78	87.5%	71.6%	31.1%	97.5%
22	14	4	28		14	32	2	77	87.5%	70.6%	30.4%	97.5%
23	15	4	28		15	32	1	77	93.8%	70.6%	31.9%	98.7%
24	15	4	28		15	32	1	77	93.8%	70.6%	31.9%	98.7%
25	15	6	35		15	41	1	68	93.8%	62.4%	26.8%	98.6%

AIMS: ABNORMAL VS NORMAL/SUSPICIOUS AT8 MONTHS ADJUSTED AGE

	16	9	100	125								
% Rank	ABN	SUS	NORM		a cell	b cell	c cell	d cell	Sensitivity	Specificity	+PV	-PV
0	13	3	3		13	6	3	103	81.2%	94.5%	68.4%	97.2%
1	13	3	4		13	7	3	102	81.2%	93.6%	65.0%	97.1%
2	13	3	5		13	8	3	101	81.2%	92.7%	61.9%	97.1%
3	13	4	5		13	9	3	100	81.2%	91.7%	59.1%	97.1%
4	14	4	6		14	10	2	99	87.5%	90.8%	58.3%	98.0%
5	16	4	6		16	10	0	99	100.0%	90.8%	61.5%	100.0%
6	16	4	6		16	10	0	99	100.0%	90.8%	61.5%	100.0%
7	16	5	7		16	12	0	97	100.0%	89.0%	57.1%	100.0%
8	16	5	8		16	13	0	96	100.0%	88.1%	55.2%	100.0%
9	16	5	10		16	15	0	94	100.0%	86.2%	51.6%	100.0%
10	16	6	14		16	20	0	89	100.0%	81.7%	44.4%	100.0%
11	16	6	15		16	21	0	88	100.0%	80.7%	43.2%	100.0%
12	16	6	16		16	22	0	87	100.0%	79.8%	42.1%	100.0%
13	16	6	16		16	22	0	87	100.0%	79.8%	42.1%	100.0%
14	16	6	16		16	22	0	87	100.0%	79.8%	42.1%	100.0%
15	16	6	17		16	23	0	86	100.0%	78.9%	41.0%	100.0%
16	16	6	17		16	23	0	86	100.0%	78.9%	41.0%	100.0%
17	16	6	19		16	25	0	84	100.0%	77.1%	39.0%	100.0%
18	16	7	22		16	29	0	80	100.0%	73.4%	35.6%	100.0%
19	16	7	22		16	29	0	80	100.0%	73.4%	35.6%	100.0%
20	16	7	25		16	32	0	77	100.0%	70.6%	33.3%	100.0%
21	16	7	26		16	33	0	76	100.0%	69.7%	32.7%	100.0%
22	16	7	29		16	36	0	73	100.0%	67.0%	30.8%	100.0%
23	16	7	29		16	36	0	73	100.0%	67.0%	30.8%	100.0%
24	16	7	30		16	37	0	72	100.0%	66.1%	30.2%	100.0%
25	16	8	38		16	46	0	63	100.0%	57.8%	25.8%	100.0%

AIMS: ABNORMAL/SUSPICIOUS VS NORMAL AT 4 MONTHS ADJUSTED AGE												
	16	9	100	125								
% Rand	ABN	SUS	NORM		a cell	b cell	c cell	d cell	Sensitivity	Specificity	+PV	-PV
0	7	1	1		8	1	17	99	32.0%	99.0%	88.9%	85.3%
1	8	2	4		10	4	15	96	40.0%	96.0%	71.4%	86.5%
2	8	2	4		10	4	15	96	40.0%	96.0%	71.4%	86.5%
3	9	2	5		11	5	14	95	44.0%	95.0%	68.8%	87.2%
4	9	2	6		11	6	14	94	44.0%	94.0%	64.7%	87.0%
5	10	3	10		13	10	12	90	52.0%	90.0%	56.5%	88.2%
6	10	3	10		13	10	12	90	52.0%	90.0%	56.5%	88.2%
7	10	3	10		13	10	12	90	52.0%	90.0%	56.5%	88.2%
8	12	3	13		15	13	10	87	60.0%	87.0%	53.6%	89.7%
9	12	3	13		15	13	10	87	60.0%	87.0%	53.6%	89.7%
10	14	4	20		18	20	7	80	72.0%	80.0%	47.4%	92.0%
11	14	4	21		18	21	7	79	72.0%	79.0%	46.2%	91.9%
12	14	4	22		18	22	7	78	72.0%	78.0%	45.0%	91.8%
13	14	4	23		18	23	7	77	72.0%	77.0%	43.9%	91.7%
14	14	4	24		18	24	7	76	72.0%	76.0%	42.9%	91.6%
15	14	4	25		18	25	7	75	72.0%	75.0%	41.9%	91.5%
16	14	4	25		18	25	7	75	72.0%	75.0%	41.9%	91.5%
17	14	4	27		18	27	7	73	72.0%	73.0%	40.0%	91.2%
18	14	4	27		18	27	7	73	72.0%	73.0%	40.0%	91.2%
19	14	4	27		18	27	7	73	72.0%	73.0%	40.0%	91.2%
20	14	4	27		18	27	7	73	72.0%	73.0%	40.0%	91.2%
21	14	4	27		18	27	7	73	72.0%	73.0%	40.0%	91.2%
22	14	4	28		18	28	7	72	72.0%	72.0%	39.1%	91.1%
23	15	4	28		19	28	6	72	76.0%	72.0%	40.4%	92.3%
24	15	4	28		19	28	6	72	76.0%	72.0%	40.4%	92.3%
25	15	6	35		21	35	4	65	84.0%	65.0%	37.5%	94.2%

AIMS: ABNORMAL/SUSPICIOUS VS NORMAL AT 8 MONTHS ADJUSTED AGE												
	16	9	100	125								
% Rank	ABN	SUS	NORM		a cell	b cell	c cell	d cell	Sensitivity	Specificity	+PV	-PV
0	13	3	3		16	3	9	97	64.0%	97.0%	84.2%	91.5%
1	13	3	4		16	4	9	96	64.0%	96.0%	80.0%	91.4%
2	13	3	5		16	5	9	95	64.0%	95.0%	76.2%	91.3%
3	13	4	5		17	5	8	95	68.0%	95.0%	77.3%	92.2%
4	14	4	6		18	6	7	94	72.0%	94.0%	75.0%	93.1%
5	16	4	6		20	6	5	94	80.0%	94.0%	76.9%	94.9%
6	16	4	6		20	6	5	94	80.0%	94.0%	76.9%	94.9%
7	16	5	7		21	7	4	93	84.0%	93.0%	75.0%	95.9%
8	16	5	8		21	8	4	92	84.0%	92.0%	72.4%	95.8%
9	16	5	10		21	10	4	90	84.0%	90.0%	67.7%	95.7%
10	16	6	14		22	14	3	86	88.0%	86.0%	61.1%	96.6%
11	16	6	15		22	15	3	85	88.0%	85.0%	59.5%	96.6%
12	16	6	16		22	16	3	84	88.0%	84.0%	57.9%	96.6%
13	16	6	16		22	16	3	84	88.0%	84.0%	57.9%	96.6%
14	16	6	16		22	16	3	84	88.0%	84.0%	57.9%	96.6%
15	16	6	17		22	17	3	83	88.0%	83.0%	56.4%	96.5%
16	16	6	17		22	17	3	83	88.0%	83.0%	56.4%	96.5%
17	16	6	19		22	19	3	81	88.0%	81.0%	53.7%	96.4%
18	16	7	22		23	22	2	78	92.0%	78.0%	51.1%	97.5%
19	16	7	22		23	22	2	78	92.0%	78.0%	51.1%	97.5%
20	16	7	25		23	25	2	75	92.0%	75.0%	47.9%	97.4%
21	16	7	26		23	26	2	74	92.0%	74.0%	46.9%	97.4%
22	16	7	29		23	29	2	71	92.0%	71.0%	44.2%	97.3%
23	16	7	29		23	29	2	71	92.0%	71.0%	44.2%	97.3%
24	16	7	30		23	30	2	70	92.0%	70.0%	43.4%	97.2%
25	16	8	38		24	38	1	62	96.0%	62.0%	38.7%	98.4%

AIMS: ABNORMAL VS NORMAL/SUSPICIOUS AT 4 MONTHS/PRETERM												
	13	9	97	119								
% Rank	ABN	SUS	NORM		a cell	b cell	c cell	d cell	Sensitivity	Specificity	+PV	-PV
0	4	1	1		4	2	9	104	30.8%	98.1%	66.7%	92.0%
1	5	2	4		5	6	8	100	38.5%	94.3%	45.5%	92.6%
2	5	2	4		5	6	8	100	38.5%	94.3%	45.5%	92.6%
3	6	2	5		6	7	7	99	46.2%	93.4%	46.2%	93.4%
4	6	2	6		6	8	7	98	46.2%	92.5%	42.9%	93.3%
5	7	3	10		7	13	6	93	53.8%	87.7%	35.0%	93.9%
6	7	3	10		7	13	6	93	53.8%	87.7%	35.0%	93.9%
7	7	3	10		7	13	6	93	53.8%	87.7%	35.0%	93.9%
8	9	3	13		9	16	4	90	69.2%	84.9%	36.0%	95.7%
9	9	3	13		9	16	4	90	69.2%	84.9%	36.0%	95.7%
10	11	4	20		11	24	2	82	84.6%	77.4%	31.4%	97.6%
11	11	4	21		11	25	2	81	84.6%	76.4%	30.6%	97.6%
12	11	4	22		11	26	2	80	84.6%	75.5%	29.7%	97.6%
13	11	4	23		11	27	2	79	84.6%	74.5%	28.9%	97.5%
14	11	4	24		11	28	2	78	84.6%	73.6%	28.2%	97.5%
15	11	4	25		11	29	2	77	84.6%	72.6%	27.5%	97.5%
16	11	4	25		11	29	2	77	84.6%	72.6%	27.5%	97.5%
17	11	4	27		11	31	2	75	84.6%	70.8%	26.2%	97.4%
18	11	4	27		11	31	2	75	84.6%	70.8%	26.2%	97.4%
19	11	4	27		11	31	2	75	84.6%	70.8%	26.2%	97.4%
20	11	4	27		11	31	2	75	84.6%	70.8%	26.2%	97.4%
21	11	4	27		11	31	2	75	84.6%	70.8%	26.2%	97.4%
22	11	4	28		11	32	2	74	84.6%	69.8%	25.6%	97.4%
23	12	4	28		12	32	1	74	92.3%	69.8%	27.3%	98.7%
24	12	4	28		12	32	1	74	92.3%	69.8%	27.3%	98.7%
25	12	6	34		12	40	1	66	92.3%	62.3%	23.1%	98.5%

AIMS: ABNORMAL VS NORMAL/SUSPICIOUS AT8 MONTHS/PRETERM												
	13	9	97	119								
% Rank	ABN	SUS	NORM		a cell	b cell	c cell	d cell	Sensitivity	Specificity	+PV	-PV
0	10	3	3		10	6	3	100	76.9%	94.3%	62.5%	97.1%
1	10	3	4		10	7	3	99	76.9%	93.4%	58.8%	97.1%
2	10	3	5		10	8	3	98	76.9%	92.5%	55.6%	97.0%
3	10	4	5		10	9	3	97	76.9%	91.5%	52.6%	97.0%
4	11	4	6		11	10	2	96	84.6%	90.6%	52.4%	98.0%
5	13	4	6		13	10	0	96	100.0%	90.6%	56.5%	100.0%
6	13	4	6		13	10	0	96	100.0%	90.6%	56.5%	100.0%
7	13	5	6		13	11	0	95	100.0%	89.6%	54.2%	100.0%
8	13	5	7		13	12	0	94	100.0%	88.7%	52.0%	100.0%
9	13	5	9		13	14	0	92	100.0%	86.8%	48.1%	100.0%
10	13	6	13		13	19	0	87	100.0%	82.1%	40.6%	100.0%
11	13	6	14		13	20	0	86	100.0%	81.1%	39.4%	100.0%
12	13	6	14		13	20	0	86	100.0%	81.1%	39.4%	100.0%
13	13	6	14		13	20	0	86	100.0%	81.1%	39.4%	100.0%
14	13	6	14		13	20	0	86	100.0%	81.1%	39.4%	100.0%
15	13	6	15		13	21	0	85	100.0%	80.2%	38.2%	100.0%
16	13	6	15		13	21	0	85	100.0%	80.2%	38.2%	100.0%
17	13	6	17		13	23	0	83	100.0%	78.3%	36.1%	100.0%
18	13	7	20		13	27	0	79	100.0%	74.5%	32.5%	100.0%
19	13	7	20		13	27	0	79	100.0%	74.5%	32.5%	100.0%
20	13	7	23		13	30	0	76	100.0%	71.7%	30.2%	100.0%
21	13	7	24		13	31	0	75	100.0%	70.8%	29.5%	100.0%
22	13	7	27		13	34	0	72	100.0%	67.9%	27.7%	100.0%
23	13	7	27		13	34	0	72	100.0%	67.9%	27.7%	100.0%
24	13	7	28		13	35	0	71	100.0%	67.0%	27.1%	100.0%
25	13	8	28		13	36	0	70	100.0%	66.0%	26.5%	100.0%

AIMS: ABNORMAL/SUSPICIOUS VS NORMAL AT 4 MONTHS/PRETERM												
	13	9	97	119								
% Rank	ABN	SUS	NORM		a cell	b cell	c cell	d cell	Sensitivity	Specificity	+PV	-PV
0	4	1	1		5	1	17	96	22.7%	99.0%	83.3%	85.0%
1	5	2	4		7	4	15	93	31.8%	95.9%	63.6%	86.1%
2	5	2	4		7	4	15	93	31.8%	95.9%	63.6%	86.1%
3	6	2	5		8	5	14	92	36.4%	94.8%	61.5%	86.8%
4	6	2	6		8	6	14	91	36.4%	93.8%	57.1%	86.7%
5	7	3	10		10	10	12	87	45.5%	89.7%	50.0%	87.9%
6	7	3	10		10	10	12	87	45.5%	89.7%	50.0%	87.9%
7	7	3	10		10	10	12	87	45.5%	89.7%	50.0%	87.9%
8	9	3	13		12	13	10	84	54.5%	86.6%	48.0%	89.4%
9	9	3	13		12	13	10	84	54.5%	86.6%	48.0%	89.4%
10	11	4	20		15	20	7	77	68.2%	79.4%	42.9%	91.7%
11	11	4	21		15	21	7	76	68.2%	78.4%	41.7%	91.6%
12	11	4	22		15	22	7	75	68.2%	77.3%	40.5%	91.5%
13	11	4	23		15	23	7	74	68.2%	76.3%	39.5%	91.4%
14	11	4	24		15	24	7	73	68.2%	75.3%	38.5%	91.2%
15	11	4	25		15	25	7	72	68.2%	74.2%	37.5%	91.1%
16	11	4	25		15	25	7	72	68.2%	74.2%	37.5%	91.1%
17	11	4	27		15	27	7	70	68.2%	72.2%	35.7%	90.9%
18	11	4	27		15	27	7	70	68.2%	72.2%	35.7%	90.9%
19	11	4	27		15	27	7	70	68.2%	72.2%	35.7%	90.9%
20	11	4	27		15	27	7	70	68.2%	72.2%	35.7%	90.9%
21	11	4	27		15	27	7	70	68.2%	72.2%	35.7%	90.9%
22	11	4	28		15	28	7	69	68.2%	71.1%	34.9%	90.8%
23	12	4	28		16	28	6	69	72.7%	71.1%	36.4%	92.0%
24	12	4	28		16	28	6	69	72.7%	71.1%	36.4%	92.0%
25	12	6	34		18	34	4	63	81.8%	64.9%	34.6%	94.0%

AIMS: ABNORMAL/SUSPICIOUS VS NORMAL AT 8 MONTHS/PRETERM												
	13	9	97	119								
% Rank	ABN	SUS	NORM		a cell	b cell	c cell	d cell	Sensitivity	Specificity	+PV	-PV
0	10	3	3		13	3	9	94	59.1%	96.9%	81.2%	91.3%
1	10	3	4		13	4	9	93	59.1%	95.9%	76.5%	91.2%
2	10	3	5		13	5	9	92	59.1%	94.8%	72.2%	91.1%
3	10	4	5		14	5	8	92	63.6%	94.8%	73.7%	92.0%
4	11	4	6		15	6	7	91	68.2%	93.8%	71.4%	92.9%
5	13	4	6		17	6	5	91	77.3%	93.8%	73.9%	94.8%
6	13	4	6		17	6	5	91	77.3%	93.8%	73.9%	94.8%
7	13	5	6		18	6	4	91	81.8%	93.8%	75.0%	95.8%
8	13	5	7		18	7	4	90	81.8%	92.8%	72.0%	95.7%
9	13	5	9		18	9	4	88	81.8%	90.7%	66.7%	95.7%
10	13	6	13		19	13	3	84	86.4%	86.6%	59.4%	96.6%
11	13	6	14		19	14	3	83	86.4%	85.6%	57.6%	96.5%
12	13	6	14		19	14	3	83	86.4%	85.6%	57.6%	96.5%
13	13	6	14		19	14	3	83	86.4%	85.6%	57.6%	96.5%
14	13	6	14		19	14	3	83	86.4%	85.6%	57.6%	96.5%
15	13	6	15		19	15	3	82	86.4%	84.5%	55.9%	96.5%
16	13	6	15		19	15	3	82	86.4%	84.5%	55.9%	96.5%
17	13	6	17		19	17	3	80	86.4%	82.5%	52.8%	96.4%
18	13	7	20		20	20	2	77	90.9%	79.4%	50.0%	97.5%
19	13	7	20		20	20	2	77	90.9%	79.4%	50.0%	97.5%
20	13	7	23		20	23	2	74	90.9%	76.3%	46.5%	97.4%
21	13	7	24		20	24	2	73	90.9%	75.3%	45.5%	97.3%
22	13	7	27		20	27	2	70	90.9%	72.2%	42.6%	97.2%
23	13	7	27		20	27	2	70	90.9%	72.2%	42.6%	97.2%
24	13	7	28		20	28	2	69	90.9%	71.1%	41.7%	97.2%
25	13	8	28		21	28	1	69	95.5%	71.1%	42.9%	98.6%